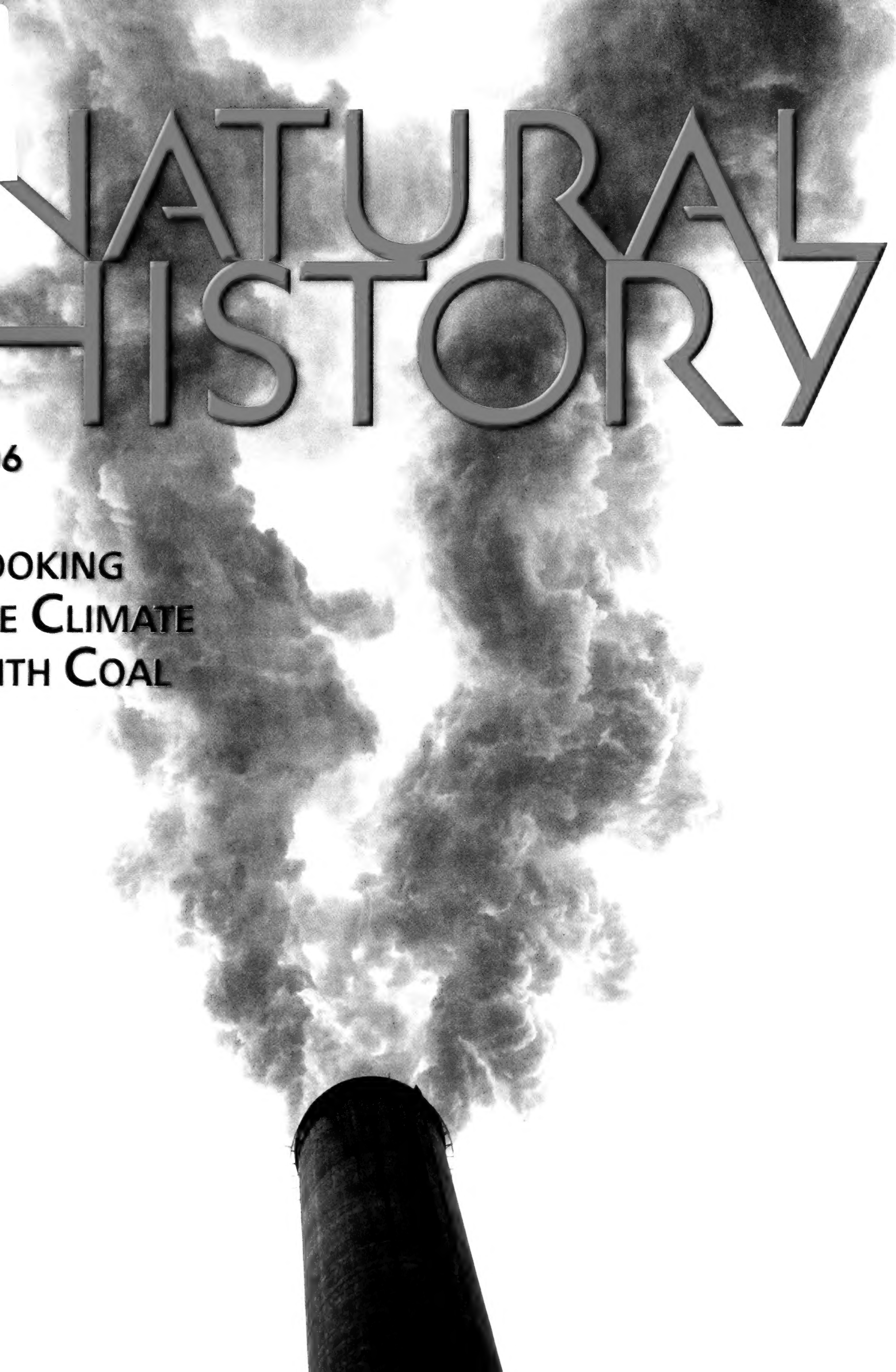
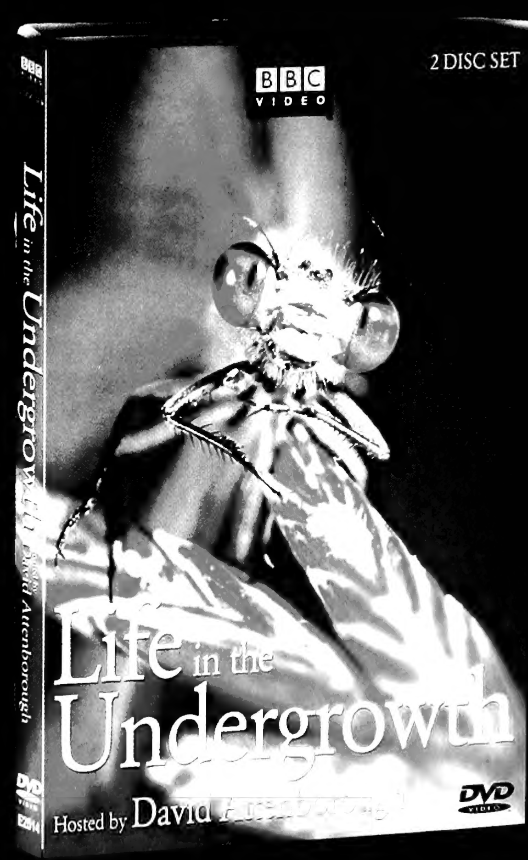
NATURAL HISTORY

5/06

Cooking The Climate With Coal



For every One of Us There Are 200 Million of Them



Discover a World Teeming with Secrets and Surprises

Join David Attenborough on his groundbreaking exploration. Thanks to technical innovations in lighting, optics andcomputerized motion control, the turbulent, super-organized world of invertebrates is finally revealed from the perspective of its extraordinary inhabitants.

Available on DVD May 2

BBC AMERICA SHOP

www.bbcamericashop.com

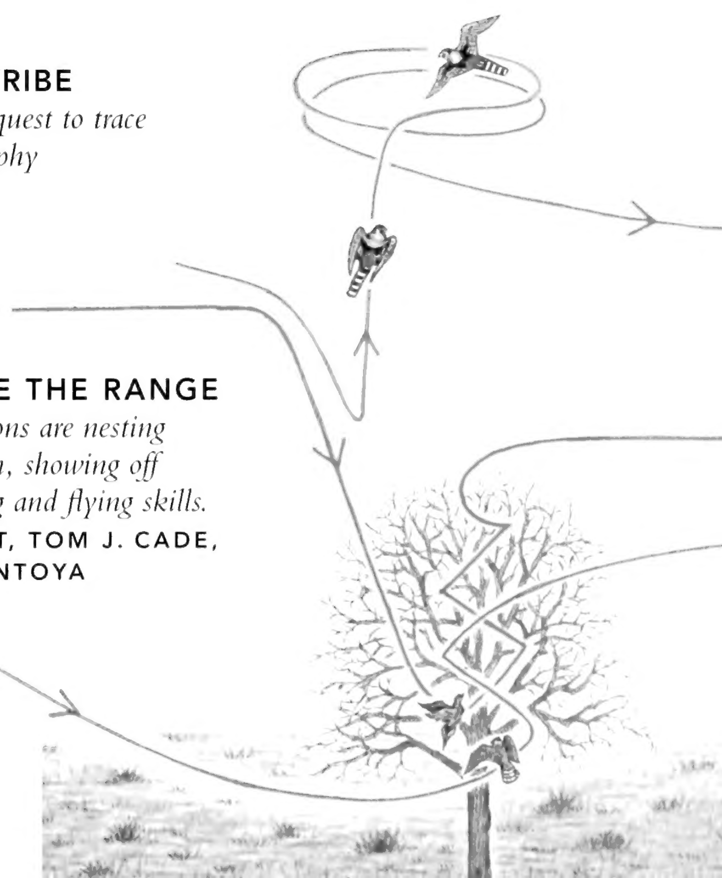
BBC VIDEO

NATURAL HISTORY

MAY 2006 VOLUME 115 NUMBER 4

COMMENTARY

FEATURES



ON THE COVER: Smokestack and emissions from a coal-fired power plant in Ohio. Photograph by Mitch Epstein

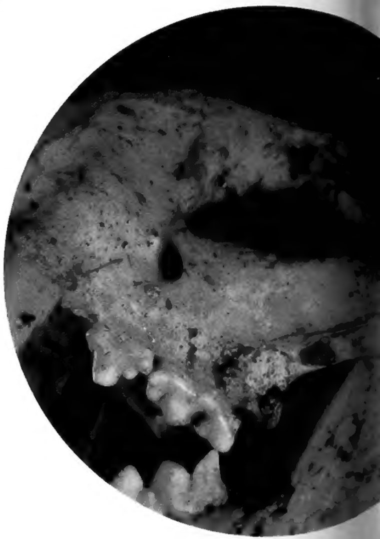
NATURAL HISTORY

DEPARTMENTS

4

12

56



72

63

PICTURE CREDITS: Page 60

Visit our Web site at www.naturalhistorymag.com


JOB DESCRIPTION:
SAVE THE PLANET.


ROLEX
SEA-DWELLER

THE NATURAL MOMENT

Camargue Cavalcade

Photograph by Steve Bloom

THE NATURAL MOMENT

◄ *See preceding two pages*

Photographer Steve Bloom stood waist-deep in marsh water of the Camargue, swatting mosquitoes while he waited for a riderless cavalry to storm his camera. And, action! A local farmer herded a group of free-roaming horses toward Bloom. A few splashes later, the horses—icons of the Camargue—whooshed past, leaving Bloom to shake the water out of his trusty camera, now in need of repair.

Bloom and other naturalists have long been enchanted with the breed of horses living in the Camargue, the triangular delta in southern France where the Rhône River meets the Mediterranean Sea. The horses—which, at a height of only thirteen or fourteen hands, actually qualify as ponies—have lived there for at least 2,500 years. They share the marshlands with millions of migratory birds, not to mention a growing population of human beings.

Easily observed, yet generally unconstrained, Camargue horses have been a boon to scientists studying their behavior and environment for several decades. Unfortunately, though, their most recent scientific contribution has been to serve as an unwitting test bed for the spread of West Nile virus. First infected in the early 1960s, the Camargue population suffered a second outbreak in 2000, when twenty-one horses died. The episode sparked a controversy about insect control—and human intervention.

Now the coastal sanctuary may be facing another invasion: the H5N1 avian flu virus. Camargue watchers like Steve Bloom will keep monitoring the wildlife, and weighing the need to intervene. —*Erin Espelie*

UP FRONT

Playing with Fire

Anyone paying attention to the news knows that many of the world's flashpoints—the war in Iraq, the politics of the Middle East, terrorism and its consequences—have grown largely out of just one issue: energy. Of course, every major effort to harness energy since the control of fire has come with serious drawbacks. But fossil fuels now pose a global problem that probably transcends even war, politics, and terrorism: the threat of global warming.

When fossil fuels burn, they release carbon dioxide (CO_2), a gas that contributes to the atmospheric greenhouse effect of trapping solar heat at the Earth's surface. And of all fossil fuels, by far the biggest troublemaker for the climate is coal. As Jeff Goodell points out ("Cooking the Climate with Coal," page 36), for every kilowatt-hour of usable energy from coal, 2.1 pounds of CO_2 are pumped into the atmosphere. (The same energy from oil releases 1.4 pounds of CO_2; from natural gas, 0.8 pound.) Yet new coal-fired power plants expected to be built in the next twenty-five years would add more than 1,350 gigawatts to the present generating capacity. If those plants are built, Goodell notes, they will produce more CO_2 in their sixty-year operating lives than all the coal burned in the past 250 years.

• • •

But so what? If sea levels rise, can't we simply move back from the shore? If the heat becomes uncomfortable, can't we just shift farther from the equator? Elizabeth Kolbert's new book, *Field Notes from a Catastrophe,* reviewed in this issue by Laurence A. Marschall ("Bookshelf," page 58), describes why some of the changes may not be so easy to swallow. Warmer temperatures are expected to drive more intense storms. Displacement of ecosystems may stir up deadly strains of bacteria or viruses. Warmer temperatures may also trigger effects that could snowball unpredictably. The Greenland ice cap—a big snowball if there ever was one—is slipping toward the sea, and the slippage is accelerating, perhaps because meltwater is lubricating the base of the ice. Organic matter in Arctic permafrost is only partly decayed; as it thaws, decay recommences and more carbon enters the atmosphere, thawing the permafrost even more. In "Gas Trap" (page 62) Robert Anderson describes what may be the scariest snowball scenario of all: Methane, a greenhouse gas twenty times more potent than carbon dioxide, is also locked up in the permafrost. So melting permafrost could also release methane into the atmosphere, further accelerating the warming trend.

There is some middling-good news, though. As Stéphan Reebs reports ("Sink in the Sea," page 12), scientists have recently discovered two "sinks" for carbon whose importance had been underestimated: krill convey organic matter to the seafloor, and mangroves, when they decay, inject dissolved organic matter into the oceans. Unfortunately, mangrove forests are declining worldwide.

• • •

Neil deGrasse Tyson is taking a break from his "Universe" column this month. He'll be back next month. —PETER BROWN

CONTRIBUTORS

A safari holiday to Africa persuaded **STEVE BLOOM** to swap his career in graphic arts for the peripatetic life of a travel photographer. Nowadays he attempts, in photographs such as his thrilling image of galloping horses in the Camargue ("The Natural Moment," page 4), to capture animals' spirits. Two new books of his photographs will be published this year, *Spirit of the Wild* (Thames & Hudson) and *Elephant!* (Thames & Hudson). More of his photos can be viewed on his Web site (www.stevebloom.com).

JEFF GOODELL ("Cooking the Climate with Coal," page 36) became interested in the coal industry in the spring of 2001, when he began research on the topic for an article for *The New York Times Magazine*. He is a contributing editor for *Rolling Stone*, and the author of numerous books including *The New York Times* bestseller, *Our Story: 77 Hours That Tested Our Friendship and Our Faith* (Hyperion, 2002), based on the experiences of nine Quecreek miners who were trapped underground, and *Sunnyvale: The Rise and Fall of a Silicon Valley Family* (Villard, 2000). In June, Houghton Mifflin will publish his latest book, *Big Coal: The Dirty Secret Behind America's Energy Future*, from which his article is adapted.

As anthropologist **EDMUND CARPENTER** ("Decoding the Tribe," page 42) explains, the independent scholar Carl Schuster (1904–1969) devoted his life to documenting ancient and tribal graphic designs. No less remarkable than Schuster's is Carpenter's career, which has ranged from collaborations with the mass-media guru Marshall McLuhan, to ethnographic fieldwork in the Arctic and New Guinea, to archaeological investigations in Siberia. Carpenter is an officer of the Rock Foundation in New York, which supports anthropological publications and films. His books include *Oh, What a Blow That Phantom Gave Me!* (Holt, Rinehart and Winston, 1972) and, with Schuster, *Patterns That Connect: Social Symbolism in Ancient & Tribal Art* (Harry N. Abrams Inc., 1996).

Hunt

Cade

Montoya

W. GRAINGER HUNT ("Home above the Range," page 48) and his co-workers at the Chihuahuan Desert Research Institute near Fort Davis, Texas, began to work on aplomado recovery in the late 1970s, when they brought the first pairs of aplomados to the United States from Mexico for captive breeding. He joined the Peregrine Fund in 2001, as senior scientist for the California condor and aplomado falcon restoration projects. **TOM J. CADE** is professor emeritus of ornithology at Cornell University in Ithaca, New York, and founding chairman of the Peregrine Fund. He has had a lifelong interest in birds of prey, particularly falcons, and is the author of *The Falcons of the World* (Cornell University Press, 1982). **ANGEL B. MONTOYA**'s interest in aplomados began in 1991, while he was a student intern at Laguna Atascosa National Wildlife Refuge in Rio Hondo, Texas. There he learned that the last known nesting of the aplomado in the U.S. was near his hometown of Deming, New Mexico, and he has monitored and studied aplomados in the grasslands of Chihuahua, Mexico ever since. He joined the Peregrine Fund as a research scientist in 1999.

NATURAL HISTORY

PETER BROWN *Editor-in-Chief*

Mary Beth Aberlin *Executive Editor*
Steven R. Black *Art Director (on leave)*

Board of Editors
Erin Espelie, Rebecca Kessler,
Mary Knight, Vittorio Maestro

Jennifer Evans *Assistant Editor*
Geoffrey Wowk *Assistant Art Director*
Hannah Black *Picture Editor*
Graciela Flores *Editor-at-Large*
Samantha Harvey, *Intern*

Contributing Editors
Robert Anderson, Avis Lang, Charles Liu,
Laurence A. Marschall, Richard Milner,
Robert H. Mohlenbrock, Joe Rao, Stéphan Reebs,
Adam Summers, Neil deGrasse Tyson

CHARLES E. HARRIS *Publisher*
Edgar L. Harrison *Advertising Director*
Gale Page *Consumer Marketing Director*
Maria Volpe *Promotion Director*
Sonia W. Paratore *National Advertising Manager*
Meredith Miller *Acting Production Manager*
Michael Shectman *Fulfillment Manager*

For advertising information
call 646-356-6508

Advertising Sales Representatives
Detroit—Barron Media Sales, LLC, 313-268-3996
Chicago—Robert Purdy & Associates, 312-726-7800
West Coast—On Course Media Sales, 310-710-7414
Toronto—American Publishers Representatives Ltd., 416-363-1388
Atlanta and Miami—Rickles and Co., 770-664-4567
National Direct Response—Smyth Media Group, 914-693-8700

TODD HAPPER *Vice President, Science Education*

Educational Advisory Board
Myles Gordon *American Museum of Natural History*
David Chesebrough *COSI Columbus*
Stephanie Ratcliffe *Natural History Museum of the Adirondacks*
Ronen Mir *SciTech Hands On Museum*
Carol Valenta *St. Louis Science Center*

NATURAL HISTORY MAGAZINE, INC.
CHARLES E. HARRIS *President, Chief Executive Officer*
CHARLES LALANNE *Chief Financial Officer*
JUDY BULLER *General Manager*
CECILE WASHINGTON *General Manager*
CHARLES RODIN *Publishing Advisor*

To contact us regarding your subscription, to order a new subscription, or to change your address, please visit our Web site www.naturalhistorymag.com or write to us at
Natural History
P.O. Box 5000, Harlan, IA 51593-0257.

Natural History (ISSN 0028-0712) is published monthly, except for combined issues in July/August and December/January, by Natural History Magazine, Inc., in affiliation with the American Museum of Natural History, Central Park West at 79th Street, New York, NY 10024. E-mail: nhmag@naturalhistorymag.com. Natural History Magazine, Inc., is solely responsible for editorial content and publishing practices. Subscriptions: $30.00 a year; for Canada and all other countries: $40.00 a year. Periodicals postage paid at New York, NY, and at additional mailing offices. Canada Publications Mail No. 40030827. If you would like to contact us regarding your subscription or to enter a new subscription, please write to us at Natural History, P.O. Box 5000, Harlan, IA 51593-0257. Postmaster: Send address changes to *Natural History*, P. O. Box 5000, Harlan, IA 51537-5000. Printed in the U.S.A.

Warning Scents?

Uldis Roze ["Smart Weapons," 3/06] and his colleagues identified R-delta-decalactone as the chemical behind the scent of an angry porcupine. But how can they be sure that the other components of the scent were unimportant? Perhaps nonhuman animals smell things that to a person are odorless. Or, perhaps other parts of the porcupine odor register more strongly in nonhuman animals.
Colin MacKenzie
Mission Hills, California

ULDIS ROZE REPLIES: Colin MacKenzie's point is well taken. Of the thousand or so olfactory receptor *(OR)* genes in the mammalian genome, roughly 60 percent are turned off (encoded as pseudogenes) in humans. That percentage is far higher than the corresponding percentage in other mammals that have been tested. But since the *OR* genes for R-delta-decalactone have not been turned off in humans, they must be important for survival, and they probably have not been turned off in other mammals either. Hence for other mammals, the olfactory portrait of a porcupine might include additional notes, but it is probably not missing a note of R-delta-decalactone.

The porcupine has chosen well in basing its warning system on that chemical. Besides being universally recognized by potential mammal predators, R-delta-decalactone is volatile, unusual, and present in high enough concentrations to pack the desired punch. No other component of the warning mixture can claim all those features.

Ancestral Disputes

Russell L. Ciochon and Gregg F. Gunnell ["Our Anthropoid Roots," 03/06] claim that recently discovered fossils contradict the longstanding view that amphipithecid primates lie near the base of the anthropoid lineage. Actually, improved knowledge of amphipithecid anatomy strengthens their anthropoid status.

In contrast to adapoids and other primitive primates, anthropoids had a reduced reliance on the sense of smell. As a result, the snouts and jaws of early anthropoids were compacted, yielding a more abbreviated, monkeylike face. Amphipithecid jaws reflect that distinctive evolutionary change: their lower premolars are reduced and crowded in a way that never occurs in adapoids. No competent paleontologist would confuse amphipithecid jaws with those of adapoids.

Amphipithecids and other fossil primates show that the roots of our extended family tree germinated in Asia millions of years earlier than was previously thought.
Chris Beard
Carnegie Museum of Natural History
Pittsburgh, Pennsylvania

On page 56, Russell Ciochon and Gregg Gunnell present a graphic summary of traits that distinguish prosimians and anthropoids. But they omit the ectotympanic, an "ear bone" that occurs in two forms in primates. Anthropoids have a tubular form, whereas prosimians (except tarsiers) have a ring form.

But New World and *Aegyptopithecus* monkeys, specimens of which were discovered in the Fayum desert in Egypt, have ring-shaped ectotympanics. Does that imply the Fayum anthropoids are not the ancestors of modern anthropoids? If so, from which primate fossils did modern anthropoids arise? The tubular form of the ectotympanic seems to first appear in early Miocene dryopithecines, the earliest species to resemble modern apes. Are paleontologists looking at a set (or sets) of parallel evolutionary sequences between "ring anthropoids" and "tubular anthropoids"?
Lyle Hubbard
Dallas, Oregon

Russell Ciochon and Gregg Gunnell propose a primate family tree (on page 57) that is more conjectural than it needs to be, given current evidence. Their proposed link among lemurs, galagos, adapoids, amphipithecids, and omomyids is not supported by any shared, advanced characteristics, whereas links among omomyids, tarsiers, and anthropoids are.

The authors also confuse time and morphology. Evolution is about documenting the morphological changes across time from primitive to more advanced forms. A species' phylogenetic position is decided by morphology, not time. If new 10-million-year-old specimens of African *Homo erectus* were found this week, the evolutionary position of *Homo erectus* relative to modern humans would remain the same, because the morphology of *Homo erectus* would not change. Similarly, the morphology of *Eosimias* marks it as a primitive member of the anthropoid lineage; its age is immaterial.
Daniel L. Gebo
Northern Illinois University
DeKalb, Illinois

RUSSELL L. CIOCHON AND GREGG F. GUNNELL REPLY: Chris Beard seems to have missed the point of our article—that until skeletal evidence of amphipithecids was discovered, their dental remains could be interpreted in a variety of ways. Now, however, skeletal elements are known that clearly indicate they were adapoids. Dental features shared by amphipithecids and anthropoids might well be convergences, a point we have discussed in detail elsewhere. Mr. Beard apparently cannot envision the possibility that a short-faced adapoid existed, but we can. We predict that when additional skeletal remains of the amphipithecids are uncovered, they will show the same primitive adapoid features.

The ectotympanic (the bone the ear drum is stretched across) takes a variety of shapes in primates, including, as Lyle Hubbard notes, a tubular and a ring form. The distributions of shapes suggest that a ring fused into the outer wall of

the middle-ear covering, like the one in New World monkeys, is primitive for anthropoids. The same configuration occurs in advanced Fayum anthropoids such as *Aegyptopithecus,* making them good candidates for being identified as the ancestors of all later-occurring and more derived anthropoids.

Daniel L. Gebo is more willing to accept the dubious evidence he and his colleagues have presented linking omomyids, tarsiers, eosimiids, and anthropoids than we are. Our figure depicts what is actually known. As for confusing time and morphology, the only thing that is confused is Mr. Gebo's interpretation of our figure. His exaggerated example of a 10-million-year-old *Homo erectus* reflects the flaw in his argument—at some point logic must override parsimony.

Signs of Life

Neil deGrasse Tyson's article, "Exoplanet Earth" [2/06], reminded me of a few questions I have had for decades: What would atomic explosions in the atmosphere look like to an observer far from Earth? Could they be seen from nearby stars? If so, wouldn't a nuclear explosion on a small, rocky, water-covered planet be an unnatural event in the universe and, thus, clearly a signal of the presence of a technological civilization?

John Marshall
Beaverton, Oregon

NEIL DEGRASSE TYSON REPLIES: Remarkably, an asteroid slamming into our atmosphere would be largely indistinguishable from the air blast of a large nuclear bomb. Each represents an enormous and singular deposit of energy. So, to an eavesdropping alien, the simplest explanation for mushroom clouds on a small, rocky planet would surely be asteroid impacts—not the preposterous idea that the planet had evolved creatures stupid enough to harness nuclear power for mutual extermination.

The famous 1908 Siberian air blast (the "Tunguska event") was caused by the explosion of an asteroid the size of a fifteen-story building when it hit Earth's atmosphere. In an instant, it released the energy equivalent of sixty atomic bombs of the kind dropped on Hiroshima. As for smaller asteroids, about the size of houses, the U.S. Strategic Command reports several dozen of them burst in the air per year, each releasing the energy of a single A-bomb.

Natural History *welcomes correspondence from readers. Letters should be sent via e-mail to* nhmag@naturalhistorymag.com *or by fax to 646-356-6511. All letters should include a daytime telephone number, and all letters may be edited for length and clarity.*

SAMPLINGS

Sink in the Sea

Two carbon sinks: mangroves in Australia (above); Antarctic krill (photograph below)

When fossil fuels burn, carbon compounds, once sequestered deep in the ground, turn into carbon dioxide and ascend into the atmosphere. There, they contribute to global warming. Scientists want to know more about any natural systems—called "carbon sinks"—that reverse the process and pull carbon out of circulation. Two recent studies highlight one of Earth's most important carbon sinks: the entrapment of organic material deep in the oceans.

Krill are small invertebrates that feed nightly in the oceans' rich surface waters, then descend to deep water. Investigators assumed that the krill descend slowly once every twenty-four hours and are thus still close to the surface when they release their waste (and the carbon it includes). Surface currents would then keep the carbon in circulation. Now, however, oceanographers Geraint A. Tarling of the Natural Environment Research Council in Cambridge, England, and Magnus L. Johnson of the University of Hull in Scarborough, England, have observed that Antarctic krill descend rapidly whenever they are full, perhaps as many as three times a night. Thus krill are probably very deep (well below 130 feet) when they release their waste, which eventually settles to the bottom. If so, the amount of carbon trapped in the Southern Ocean could be 8 percent greater than previously thought.

Some of the oceans' carbon comes from land. Mangroves grow in tidal flats and, like all plants, build their tissue from carbon dioxide they extract from air. When mangrove debris rots, it leaches dissolved organic matter into the sea. Thorsten Dittmar, an oceanographer at Florida State University in Tallahassee, and three colleagues estimate that though mangroves cover less than 0.1 percent of the Earth's land, they contribute more than 10 percent of all the organic carbon transferred from land to sea. They reached their conclusion by analyzing carbon isotopes to determine the origin of dissolved organic matter in water off the mangrove-rich coast of Brazil. Alas, mangroves are declining worldwide; they're trapping less carbon in the oceans just when we need them to trap more. (*Current Biology* **16**:R83–4, 2006; *Global Biogeochemical Cycles* **20**:GB1012, 2006) *—Stéphan Reebs*

Ear to the Ground

When elephants bellow warnings of danger, their low-frequency calls resound in the air and rumble through the ground. Of course, no one has ever doubted that elephants hear and respond to the airborne sounds—their ears are not exactly hidden. But whether they could detect underground vibrations has, until now, been unclear. A team led by Caitlin O'Connell-Rodwell, a biologist at Stanford University, recently demonstrated that African elephants not only perceive each other's seismic warnings, but respond to them, too.

O'Connell-Rodwell's team recorded seismic components of vocal alarms. They played the alarms back to elephants at a popular watering hole in Namibia through transmitters buried three feet underground and a hundred feet away. The elephants responded by grouping more closely together with their bodies perpendicular to the alarm source (perhaps to better perceive the warning), and by leaving the watering hole sooner than unperturbed elephants. Acoustic alarms prompted more dramatic responses than underfoot rumbles alone did, suggesting that the elephants interpreted the seismic alarms as coming from too far away to signal any imminent danger.

How elephants detect seismic signals is unknown; perhaps their trunks, pressed to the ground, or feet pick up the rumbles. Elephants thus join certain insects, amphibians, reptiles, and small mammals in taking advantage of underground communications. (*Behavioral Ecology and Sociobiology* **59**:842–50, 2006) *—Samantha Harvey*

Follow My Eyes

Following someone else's gaze is irresistible, isn't it? And people aren't the only ones who do it. Many monkey species are known to follow other monkeys' glances. It's no mystery why this behavior evolved; after all, a fellow monkey's gaze could disclose important information—say, the location of a tasty fruit or a lurking rival.

Rhesus macaques: leading by looking

But each group has many sets of watchful eyes, and deciding whose eyes to follow isn't always easy. The key is social status, according to Stephen V. Shepherd and Michael L. Platt, neurobiologists at Duke University in Durham, North Carolina, and a colleague. The team tested gaze-following behavior in rhesus macaques and observed that low-status members of the group almost immediately followed the gaze of any other monkey. High-status macaques, however, followed only the gazes of other high-ranking individuals, and took longer to do it. The difference in response times suggests that gaze-following is both reflexive and voluntary. Low-status monkeys behave reflexively because they face possible threats from other members of the group as well as predators. They need to monitor every nearby individual. But high-status monkeys are relatively safe from most other members of their group; within the group, only their social peers present a big threat. That's why they take a little time to make sure they know the social status of an individual before choosing to follow its eyes. (*Current Biology* **16**:R119–20, 2006) *—Nick W. Atkinson*

Typhoid Athena

The Plague of Athens broke out in 430 B.C. Four years later it had killed about a third of the Athenian population, contributing to the great city-state's downfall. The historian Thucydides, who himself suffered and recovered from the plague, recorded the epidemic's grim symptoms, which included fever, rash, and diarrhea. Until now, his account provided the only evidence bearing on one of medicine's most controversial enigmas: which disease, exactly, was the plague, and what pathogen caused it?

Many of the usual nefarious suspects have been brought into the lineup—the causative agents of anthrax, bubonic plague, smallpox, and tuberculosis, among others. Now, Manolis J. Papagrigorakis, a research dentist at the University of Athens, and three colleagues think they can issue an indictment in the centuries-old medical case.

The investigators studied DNA from dental pulp (the soft tissue inside teeth) of presumed plague victims unearthed from a mass grave in the ancient Kerameikos cemetery of Athens. They tried to match genetic sequences to those of several epidemic-causing microorganisms. The one they found in the victims' teeth was the bacterium *Salmonella* Typhi, the germ that causes typhoid fever. In ancient times, typhoid was untreatable; it is transmitted via contaminated food or water. That makes sense, the investigators note. At the time of the plague, Athens, in the throes of the Peloponnesian War with Sparta, was besieged and overcrowded. The overcrowding, together with unsanitary water supplies, might have caused the disease to spread . . . like the plague. (*International Journal of Infectious Diseases*, in press, 2006)

—*Graciela Flores*

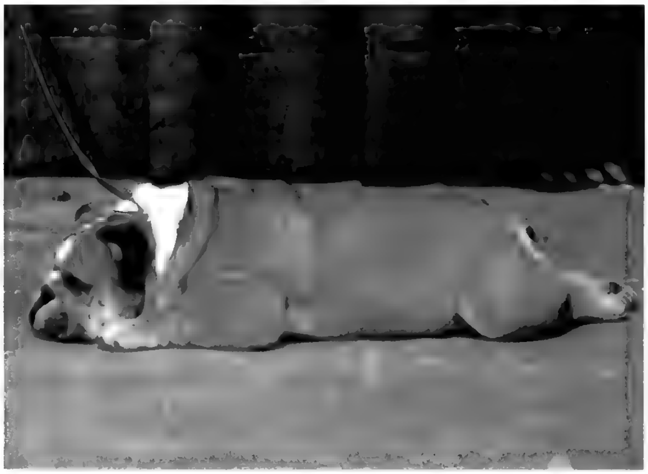
Hippocrates tends the sick and dying in Athens.

Dogs Gone Mild

Of all domestic animals, dogs have been with people the longest—archaeology says 14,000 years, though DNA hints at 40,000 years. Artificial selection has led to a multitude of breeds with physical and behavioral characteristics suited to specific jobs. Muscular, aggressive, fearless terriers, for instance, were bred to catch vermin and to fight; robust, sociable sporting dogs were bred to help people retrieve shot game. But times have changed. Kenth Svartberg, a zoologist at Stockholm University, has shown that modern dogs serve functions rather different from their traditional ones, and their personalities are changing accordingly.

In Sweden, most dogs are now bred for shows or as family pets, no matter what their breed's original purpose. Only a few breeds remain popular in working trials, let alone active on the job. Svartberg rated more than 13,000 Swedish dogs, of thirty-one breeds, for aggressiveness, curiosity, playfulness, and sociability. A dog's personality, he found, correlated better with its breed's current use as show dogs or family pets than with its traditional use. In addition, breeds now popular in dog shows, such as pinschers or dalmatians, seem to be losing their character: they scored low on all four of Svartberg's scales. In comparison, working breeds, such as border collies, are more aggressive and playful, whereas popular family pet breeds, such as golden retrievers, are more playful and sociable. Artificial selection of dogs seems to be ongoing, though, intriguingly, it is pushing the personalities of show dogs and pets in opposite directions. (*Applied Animal Behaviour Science* **96**:293–313, 2006)

—*S.R.*



Selected, but for what?

Goat-Getters

If Neanderthals still walked the earth, they could be excused for developing an inferiority complex. Pop culture, as well as serious anthropology, has saddled them with all kinds of second-rate traits, from clumsiness to sheer stupidity. But Neanderthals are beginning to find more friends among anthropologists. One study has already debunked the idea that Neanderthals were clumsy tool-handlers [*see "Bones of Contention," July/August 2003*]. Now a new study by Daniel S. Adler of the University of Connecticut in Storrs and his colleagues suggests that Neanderthals' hunting skills may have been just as good as those of the *Homo sapiens* that followed.

Adler and his team analyzed animal bones from a rock shelter in the Republic of Georgia that housed Neanderthals and then modern humans for some 30,000 years. The study shows that the two societies were equally successful at hunting prime adult Caucasian tur, a seasonally abundant species of mountain goat.

But Neanderthals' reputations are not completely redeemed. Evidence at the Georgian site suggests both groups obtained raw materials such as obsidian from as far as sixty miles away. Modern humans, however, made more frequent forays and had larger territories. Adler's group believes modern humans thus developed larger social networks than Neanderthals did, perhaps because their communications were better. This social advantage enabled them to outcompete their now-extinct cousins. (*Current Anthropology* **47**:89–118, 2006) —*S.R.*

Green Repellent

Frogs' skins are veritable laboratories for synthesizing biologically active compounds, including antibiotics, glues, hallucinogens, lubricants, painkillers, and a stunning array of poisons. Now, yet another active—and potentially useful—compound has been identified in the frog's chemistry set: an insect repellent.

Health concerns have prompted a push to replace widely used synthetic insect repellents, such as diethyl-m-toluamide (DEET), which is toxic at high doses. To biologists Craig R. Williams of James Cook University in Cairns, Australia, and Michael J. Tyler of the University of Adelaide and their colleagues, frogs—with their remarkable chemical repertoires and susceptibility to insect bites—seemed a promising source of anti-insect compounds.

Australian green tree frog repels the mozzies.

The team collected skin secretions from five species of Australian frog. They swabbed the tails of mice with secretions from one species, the Australian green tree frog *(Litoria caerulea)*, and confined the mice in chambers with mosquitoes. The mice, they found, remained bite-free for about fifty minutes. By comparison, untreated mice had only twelve minutes of peace before the mosquitoes attacked; DEET-swabbed mice lasted two hours. The investigators also discovered that the secretions of two other frog species exude a mosquito-repellent odor. Williams suspects that terpenes, insect-repellent compounds that the Australian green tree frog is known to accumulate from its food, may help keep the bugs away. (*Biology Letters*, in press, 2006) —*Sion E. Rogers*

Hot Rocks

As our planet warms, rising air and ocean temperatures make frequent headlines. Of course, the land is warming, too—yet remarkably, until recently, no one had quantified just how much the continental landmasses have warmed. Now Shaopeng Huang, a geologist at the University of Michigan in Ann Arbor, has made the first analysis of the annual change in the heat content of all the Earth's continental land masses except Antarctica.

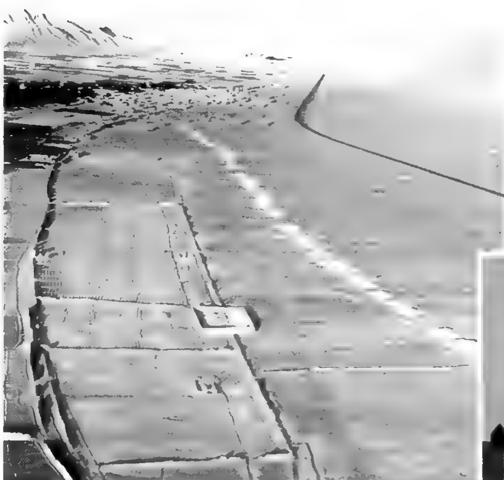
Huang made his estimates from global meteorological records, as well as from the thermal properties of the uppermost layers of the Earth's crust. Between 1851 and 2004, he discovered, a total of 11.7 zettajoules (10^{21} joules) of thermal energy has been collectively trapped by Africa, Asia, Australia, Europe, North America, and South America. That amount is equal to the world's total energy production from 1970 until 2003, and is enough to raise the temperature of the top hundred feet of the world's landmasses by two degrees Fahrenheit (1.1 degree Celsius). Even more disturbing, 10 percent of that heat—1.34 zettajoules—was absorbed in the most recent 2.6 percent of the time interval: the four years from 2001 until 2004. The effects of the warming land on biological, chemical, and physical processes are still unknown—but, says Huang, they are likely to be profound. (*Geophysical Research Letters* 33:L04707, 2006 —*G.F.*

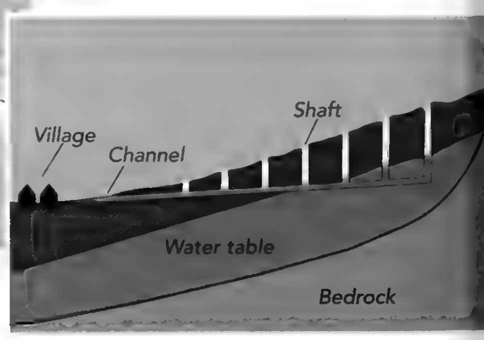
Long Dig

Unless you're a Scrabble player, you may never have heard of *qanats*. They are gently inclined underground channels that bear water from an upslope aquifer to a village in the valley below. The first qanats were built in Iran as early as 3,000 years ago; they also occur in arid parts of China, the Arabian Peninsula, and Mediterranean lands.

To avoid flooding, qanat construction proceeded upslope from the exit to a well at the source, which could be as far as fifty miles away. The builders dug a series of vertical shafts about 200 feet apart, and linked the shafts' bottoms to form the underground channel [*see illustration at bottom right*]. But how did the ancient qanat diggers, who had only imprecise surveying instruments, manage to accurately aim their digging and keep the tunnels' slopes even over great distances?

Redundant measurements were the key to success, says Stathis C. Stiros, a civil engineer at Patras University in Greece. Stiros argues that the dig planners measured the ground repeatedly, with various instruments at numerous times of day and throughout the year (light refraction, for instance, varies with outside temperature, and presents a common source of surveying error). The process randomized the engineers' inevitable errors, which then cancelled one another out. The dig planners paid for their precision with time. A Roman-era qanat in Algeria took fifteen years to build, but ten of them were devoted to planning alone. (*Journal of Archaeological Science*, in press, 2006) —*S.R.*





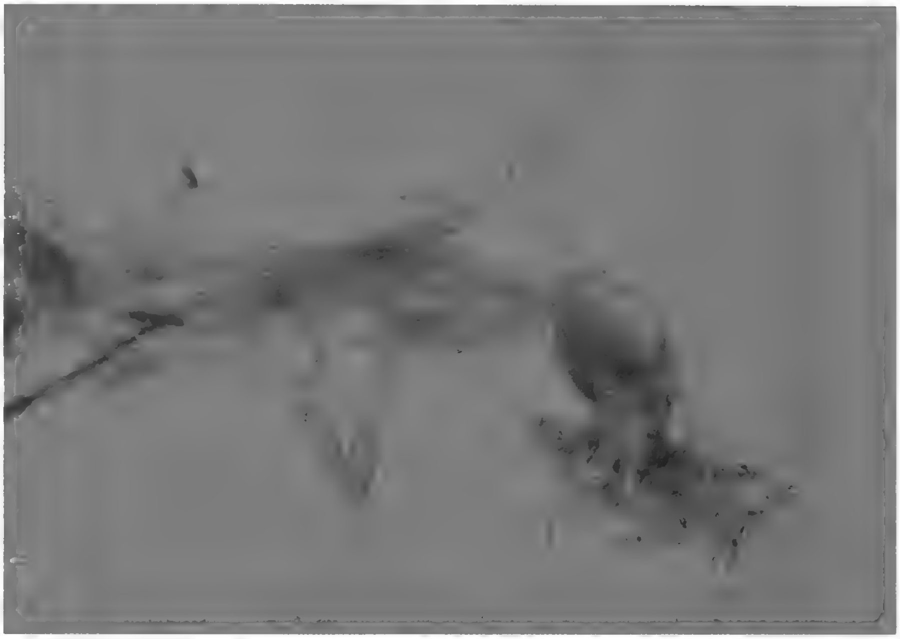
Qanat-shaft openings recede across the Iranian countryside (above); a schematic diagram of a qanat is shown at right.

Golden Tomb Fit for a Queen

Ancient ants preserved in amber show that the insects have farmed mealybug "cattle" for at least 15 million years.

By John S. LaPolla

Let's travel far back in time to a clear, sunny morning between 15 and 20 million years ago in a tropical Caribbean forest. A gentle rain the night before has softened and moistened the ground. Out through the warm, loose earth a small worker ant pokes her head and, for the first time in her life, gazes on the sunlit world. She dislikes the light and would normally shun it, but today she puts up with it in order to clear a small opening. Several of her sisters are emerging nearby, also digging small holes that link their underground nest to the outside world. When their work is complete, the workers scurry to the safety of their dark home. For a few minutes, all is still.



Ancient amber from the Dominican Republic, between 15 and 20 million years old, preserves the fossil of an ant queen (Acropyga glaesaria) *on her nuptial flight. In her mandibles the ant clutches a small mealybug* (Electromyrmoccus reginae)*, whose progeny would have produced food for the new ant colony the queen might have founded. Instead, both insects became stuck in tree resin and then entombed as the resin turned to amber. The ant's behavior—dubbed trophophoresy ("carrying food")—still occurs in modern species of* Acropyga. *The image is magnified 45×.*

Then, dozens of virgin winged queens and males crawl out of the same holes. Stretching their wings, the reproductives—as queens and male ants are collectively called—make their way up the stems of plants and the sides of small rocks to reach the highest points they can. From there, they take flight.

Such an event actually took place during the Miocene period, on what today is the Caribbean island of Hispaniola. Once the ants mated, the luckiest few among the queens—the ones not killed in accidents or through predation—started new colonies. As for the males, their goal in life was complete, and they soon died.

Nuptial flights continue to this day among ants. In North America they often take place from spring through fall, an event that many anxious homeowners mistake for an invasion of house-ravaging termites. But there was something special about the flights millions of years ago, something shared by only a few groups of ants today. When the queens took off, each one held a small, white mealybug in her mandibles, a rare ant behavior I have termed trophophoresy (meaning loosely, "carrying food"). The mealybugs held by the queens became the ancestors of herds of mealybugs (the ants' "cows") that would become "corralled" in each new ant colony, providing the ants with food.

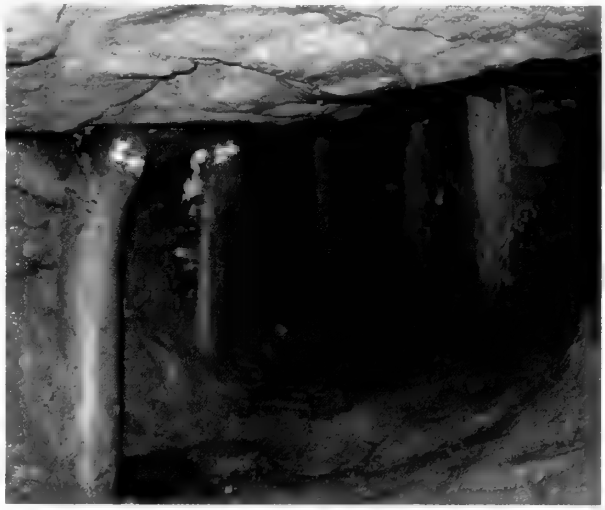
But not all the ancient queens reached their new homes. Some reproductives met their demise when they ventured too close to a species of algarrobo tree—*Hymenaea protera*—and became trapped in its sticky resin. However unfortunate the entrapment proved for the queens and the mealybugs they carried, it turned out to be good news for modern biologists. In the millions of intervening years, the resin turned into amber, and the ants entombed in the amber became fossils. Time seemed to have stopped around them, until one day their remains were discovered in a Dominican amber mine.

As it happens, a few years ago I examined a fossil of one ant queen and her mealybug in a piece of amber and

quickly recognized that the queen was a species new to science. But the specimen as a whole is immensely important as well. It demonstrates that investigators seeking to understand the evolution of certain behaviors—in this case, trophophoresy in ants—have only to look closely at the life-forms encased in amber for a golden window on a former world.

The *H. protera* tree, a long-extinct, evergreen member of the legume family, was essential to the process of fossilization. The tree exuded copious quantities of resin to protect its fragile inner layers when they were exposed to damage, perhaps after a violent windstorm had ripped off a branch or wood-boring beetles had attacked its trunk. Soon after the ant queens were trapped, the resin began to harden and draw moisture out of the ant carcasses and thus helped prevent them from decomposing. When the trees died and disappeared, the ants and mealybugs remained entombed in chunks of resin that were buried at the site. As millions of years passed, the resin continued to harden, becoming first copal and, finally, amber. There is some debate about the precise difference between copal and amber, but most experts agree that amber must be roughly the hardness of gypsum or calcite (between two and three Mohs) and that its surface should not become sticky when exposed to an organic solvent such as acetone.

Deposits of amber fossils have been found in only a handful of places around the globe. After the Baltic region, the Dominican Republic—half of the island of Hispaniola—is the second largest producer of amber in the world. There are three main mining areas for Dominican amber: La Cordillera Septentrional in the north, and Byaguana and Sabana in the east. The mines, according to George Poinar Jr. and Roberta Poinar, in their book *The Amber Forest,* are "small, tortuous tunnels carved into the sides of the mountains, or sometimes pits sunk deep into the ground" [*see photograph below*]. Miners usually have to crawl through the tunnels and chip away at rock with hammers and chisels, looking for amber. The work is hard and dangerous, and the small mines can collapse without warning.



Amber mines in the Dominican Republic are the second largest source of amber in the world, but passages are low and working conditions are often hard and dangerous. Wooden supports for the walls and ceilings often fail to prevent the mines from collapsing.

Most amber carries no traces of life. But fortunately for paleobiologists, many creatures did meet a sticky end. Flowers, leaves, seeds, insects, spiders, scorpions, and even small vertebrates such as frogs and lizards have been discovered encased in amber. Not only can such fossils tell a great deal about the form and structure of ancient species; they can also show how lineages of organisms have been distributed around the world through time. For example, one genus of ant, *Leptomyrmex,* which lives today only in eastern Australia, New Caledonia, New Guinea, and Seram, in Indonesia, has been discovered inside Dominican amber. *Lep-*

tomyrmex, therefore, must have lived on the other side of the world, probably between 15 and 20 million years ago.

When Hispaniola formed, 65 million years ago, it did not occupy its present position in the Caribbean. It arose between North and South America, roughly where Central America is today, as part of a group of islands that included modern-day Cuba, Jamaica, and Puerto Rico. For the first 5 million years of its existence, Hispaniola was close enough to what is now southern Mexico that organisms could readily travel there from the mainland. About 60 million years ago, however, the island began drifting eastward out to sea, stranding its immigrant species. Some of those species eventually became extinct—such as the forests of algarrobo trees that gave rise to Dominican amber. Other species became the founding organisms for diverse species that evolved and radiated into a number of previously unoccupied niches.

When the piece of amber containing "my" ant queen and her mealybug were chiseled out of a wall in a Dominican mine, they began a new journey, one that would help fill in part of the history of an ancient genus of ants. After the amber was polished and examined, investigators realized that the specimens inside displayed exactly the same kind of rare behavior I had described among modern-day ants. The queen had been frozen in the amber clutching a mealybug in her mandibles [*see photomicrograph on page 16*]. When I got the chance to study the fossil, I was thrilled to realize that the queen represented a new species with an intriguing form and structure that would help me understand the evolution of the genus. I named the new species *Acropyga glaesaria* (*glaesaria* means "of amber" in Latin).

Although *A. glaesaria* went extinct long ago, the genus *Acropyga* still exists today. And like their Miocene ancestors, modern-day *Acropyga* still engage in trophophoresy. Species in the genus live mostly in the warm, wet places around the world that hug the equator—though there are a few excep-

tions. *Acropyga epedana,* for instance, inhabits the dry mountains of southeastern Arizona [*see photograph on page 22*].

The behavior of modern species of *Acropyga* shows a great deal about what life was probably like for *A. glaesaria.* All *Acropyga* species are small, yellowish ants, with workers no bigger than two to four millimeters long. The ants live almost entirely underground. The workers retreat quickly when exposed to light, as the burrowing workers on prehistoric Hispaniola may have done. Instead of foraging aboveground, a common practice among many ants, *Acropyga* workers remain in underground chambers, where they "herd" and "milk" the insect equivalent of cattle. The "cattle" for the *Acropyga* are small, white mealybugs that feed on the underground roots of various plants. As the mealybugs feed, they secrete a sugar-rich fluid called honeydew, which seems to meet all the nutritional requirements of the ants. It seems as if each species of *Acropyga* has a single—or, in some cases, a few—species of mealybug associated with it.

I have studied *Acropyga* ants from Arizona to Guyana to South Africa. To find them, you turn stones over one by one and patiently break apart rotting logs, looking for tiny, slow-moving golden flecks. During my field studies in Guyana, I was fortunate enough to discover three new *Acropyga* species, along with two new species of mealybugs associated with *Acropyga.* Finding and identifying the mealybugs that live with *Acropyga* is the first step in understanding the organisms' complex symbiotic relationship.

Some of the most familiar species of mealybug live aboveground; they are well known because some are garden pests. By contrast, the various species tended by *Acropyga* depend entirely on the ants for protection and survival, just as the ants rely on them for food. That special kind of symbiosis is known as trophobiosis—ants care for another organism, called the trophobiont, in exchange for food. Many other ant species, in genera other than *Acropyga,* gather honeydew from insects such as mealybugs and aphids. In fact, in North America it is common to see ants tend-

Worker ant (A. acutiventris), belonging to the same genus as the fossilized ant in the photomicrograph on page 16, carries a white mealybug to another part of her nest. At the bottom of the image, a "herd" of mealybugs congregates near a plant root. Biologists think ants and their mealybug "cattle" may have co-evolved.

The three

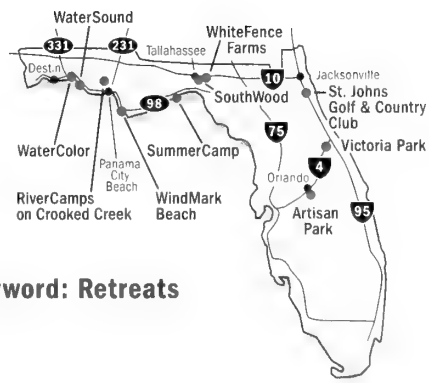
most important words

in real estate:

Location. Location. Imagination.

ST JOE

The imagination knows no limits. And across 800,000 exceptional acres, we can really stretch ours. As the largest private landholder in Florida, St. Joe offers the greatest choice of authentic, organic, and original places to live, work, and escape.



Engage *your* imagination now. Call 1-866-785-6307 or visit JOE.com | Keyword: Retreats

I F Y O U D O N ' T K N O W J O E , Y O U D O N ' T K N O W F L O R I D A .

EQUAL HOUSING OPPORTUNITY

NYSE: JOE

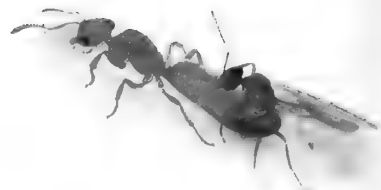
ing aphids on plants such as roses.

But the trophobiosis between *Acropyga* and their mealybugs is a particularly strong relationship. *Acropyga*'s unusual dependence is demonstrated by the queen's behavior on her nuptial flight. A queen carries only one item in her trousseau: a live mealybug clamped in her mandibles. Somehow—how, exactly, remains a mystery—that single mealybug will proliferate into an entire herd, ample food for the queen's new colony. Perhaps mealybugs reproduce from unfertilized eggs, as some insects do. Perhaps the *Acropyga* queen makes sure she carries a pregnant mealybug. Or perhaps multiple queens combine forces to found a nest together, thus supplying more than one mealybug for the herd.

Some evidence suggests that ants and mealybugs have co-evolved; in other words, evolutionary changes in one might have come about because of evolutionary changes in the other, and vice versa. Each time a new *Acropyga* species evolved, a new species of mealybug may have evolved as well. Much more research is needed, however, before investigators will know for sure.

Just as observations of modern species illustrate how *A. glaesaria* probably lived, amber fossils also provide important details about the evolution of modern *Acropyga* behavior. The ancient formation of Dominican amber implies that trophophoresy is an ancient behavior. Look at it this way: People began raising cattle for milk about 6,000 years ago, but at least 15 million years before then, *A. glaesaria* were already transporting their mealybug livestock to their new nests!

The distribution and variations among living species of *Acropyga* lead me to think that, in fact, the genus originated even earlier than the Miocene period, perhaps as early as the Cretaceous period, between 144 and 65 million years ago. My research on the forms and structures of ants indicates that the oldest *Acropyga* lineages live in Africa. If I am right, the genus *Acropyga* is probably much older than *A. glaesaria*. *Acropyga* species are poor dispersers, so it would



Ant queen (A. epedana) (large, golden insect), even while mating, keeps a grip on the white mealybug she is carrying in her mandibles on her nuptial journey. The male (small, dark ant) will soon die, and the queen will found a new colony. Having already shed her wings, she won't be burdened by them as she digs an underground nest. The mealybug will proliferate into a herd that will sustain the queen's progeny.

be hard to explain their present distribution in tropical areas worldwide if the origin of the genus did not stretch back to a time when the continents were closer together. It is possible that little *Acropyga* queens may have been toting mealybugs to their new nests when dinosaurs still roamed the Earth.

The intimate and ancient relationship between *Acropyga* ants and mealybugs offers biologists a chance to study the evolution of a complex kind of symbiosis. Not only can this example inform questions about how symbiotic relationships evolve between organisms in general, but it may also have some practical implications for human agriculture. *Acropyga* have been herding mealybugs for so long that their successes may help investigators address how people, too, can sustain agriculture for the long term. One thing remains certain: as more field studies of *Acropyga* are conducted, more specimens are pondered under the microscope, and perhaps more fossils are found, there will undoubtedly be plenty of surprises driving further study of this fascinating group of ants.

JOHN S. LAPOLLA has been fascinated by ants since childhood, when he often convinced his mother to collect ant nests with him. He is a postdoctoral fellow at the National Museum of Natural History in Washington, D.C., and will be taking a position as assistant professor of biological sciences at Towson University in Maryland in the fall.

SCENIC BYWAYS

MONTANA

The lakes and fish are big, the mountains are big, the valleys are big, and even the sky is big—Montana is Big Sky Country.

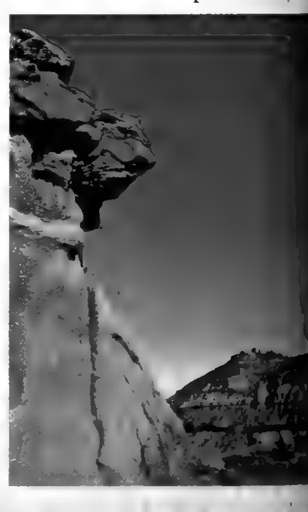
IN MONTANA, NATURE is on display everywhere. The eastern part of the state has badlands, plains, and the breaks of the Missouri River; the west has the towering Rocky Mountain range and the Continental Divide, ancient forests, and valleys formed by once-giant glacial lakes. The south has Yellowstone, the country's first national park, and the north has Glacier National Park, with millions of acres of pristine backcountry that have made it a premier destination for hikers.

Both national parks are prime spots to see wildlife. In Glacier, you may see elk, moose, and deer foraging; mountain goats and bighorn sheep; and black and grizzly bears. Yellowstone has trumpeter swans, grizzly bears, elk, bison, wolves, and many others. But you don't have to be in a national park to see wildlife; this entire state is like a gigantic nature preserve. Animals outnumber people, and there are 250 types of birds, world-class populations of wild trout, and the most diverse collection of mammals in the country.

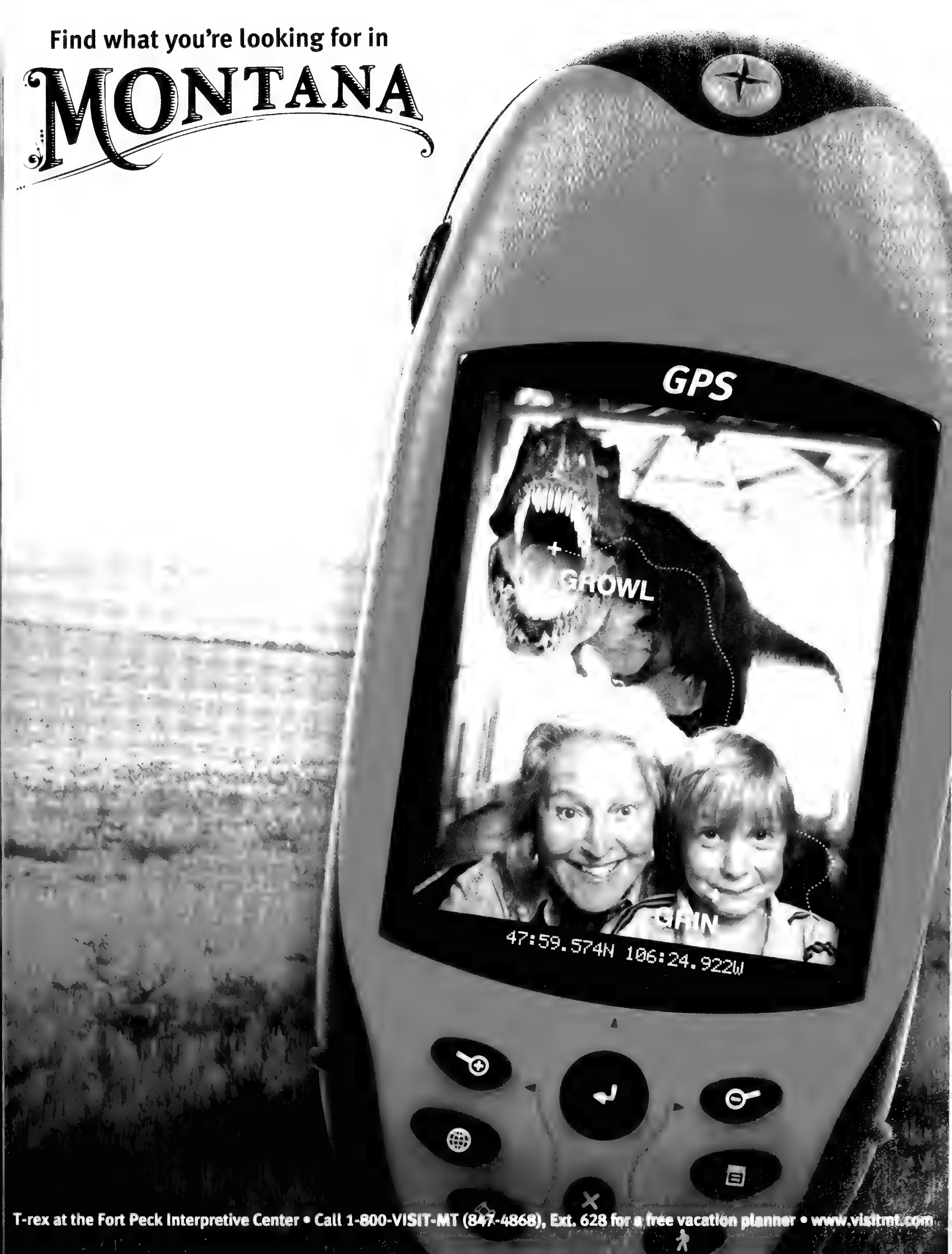
Montana has hundreds of residents per square mile—but only six of them are people.

Montana has five Scenic Byways and three Back Country Byways, but there are scenic roads everywhere. The Beartooth Scenic Byway was named "the most beautiful roadway in America" by Charles Kuralt. Completed in 1936, the highway climbs to almost 11,000 feet above sea level as it winds its way between the northeastern entrance to the park and the town of Red Lodge, traversing a range of ecosystems—from lodgepole pine forests to alpine tundra. The highway's summit is a sky-high world of glacial cirques, clear alpine lakes, and snow. In late June and July, the alpine tundra blossoms with wildflowers, including shooting stars, columbine, and Indian paintbrush. In this high country—there are twenty mountains over 12,000 feet tall—wildlife is easy to see. There are hundreds of miles of trails along the route and almost a thousand alpine lakes.

When you reach the old mining town of Red Lodge, refuel at a downtown café, then head east on Highway 308, where you can enjoy an Old West landscape of junipers, sagebrush, cowboys, and cattle. For a complete listing of scenic drives and wildlife refuges in Montana, log onto www://visitmt.com.



Top from left to right: Springtime in Glacier National Park; exploring Montana on horseback; a large herd of buffalo roams the National Bison Range, Moiese; badlands of Makoshika State Park, Glendive


Find what you're looking for in
MONTANA
GPS
GROWL
GRIN
47:59.574N 106:24.922W
T-rex at the Fort Peck Interpretive Center • Call 1-800-VISIT-MT (847-4868), Ext. 628 for a free vacation planner • www.visitmt.com

Montana is so big with such dramatically different landscapes—from mountainous forests to badlands—that it's divided into six vacation regions called "countries."

Russell Country

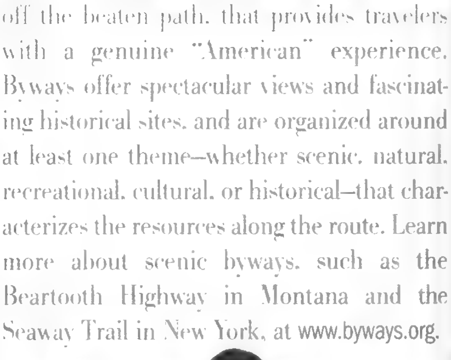
RUSSELL COUNTRY, IN NORTH-CENTRAL MONTANA, IS named after the cowboy artist Charlie M. Russell, whose canvases captured the rugged beauty of its Old West landscapes. To see these landscapes, explore Russell Country's trails and scenic byways. The Missouri Breaks Back Country Byway, beginning in Winifred, is a roughly two- to three-hour, eighty-mile drive through an ecologically unique and historically significant area. Lewis and Clark first described the area as "deserts of America," but fur traders later named it the "badlands." Travelers may encounter antelope, white-tailed and mule deer, elk, bighorn sheep, and prairie dogs.

Hiking, Rocky Mountain Front

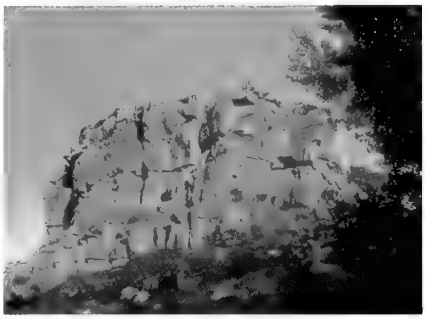
Seventy-one-mile Kings Hill Scenic Byway, beginning near White Sulphur Springs, winds its way north through the Lewis and Clark National Forest and along pristine mountain streams. You'll see plenty of wildlife on this leisurely two-hour drive. Gravel roads that criss-cross the highway lead to spectacular mountain scenery, high country lakes, trailheads, and old mines. The Northern Continental Divide Scenic Loop circles one of the largest expanses of wilderness in the lower 48 states and one of the most intact mountainous ecosystems. The C. M. Russell Auto Tour, between Great Falls and Lewistown, takes you through the landscapes that fascinated Charlie Russell. Call 800-527-5348 for a booklet comparing the paintings with the vistas that inspired them. Go to www.russell.visitmt.com for more information.

What Is a Scenic Byway?

A SCENIC BYWAY IS A ROAD WITH A story to tell—a secondary road less traveled, off the beaten path, that provides travelers with a genuine "American" experience. Byways offer spectacular views and fascinating historical sites, and are organized around at least one theme—whether scenic, natural, recreational, cultural, or historical—that characterizes the resources along the route. Learn more about scenic byways, such as the Beartooth Highway in Montana and the Seaway Trail in New York, at www.byways.org.



Dig Up a Historic Experience in Custer Country


Pompeys Pillar

CAN YOU DIG IT? YES, YOU can, with permission. Custer Country, most famous for the Battle of the Little Bighorn, is becoming widely known as one of the last places on Earth where dinosaurs lived. That's why dinosaur hunters and amateur paleontologists love visiting southeast Montana. Custer Country is home to two of the fourteen stops on the new Montana Dinosaur Trail. There are museums and parks devoted to dinosaurs, and you can even participate in a real fossil dig—all while enjoying the breathtaking scenery of Montana's most historic region.

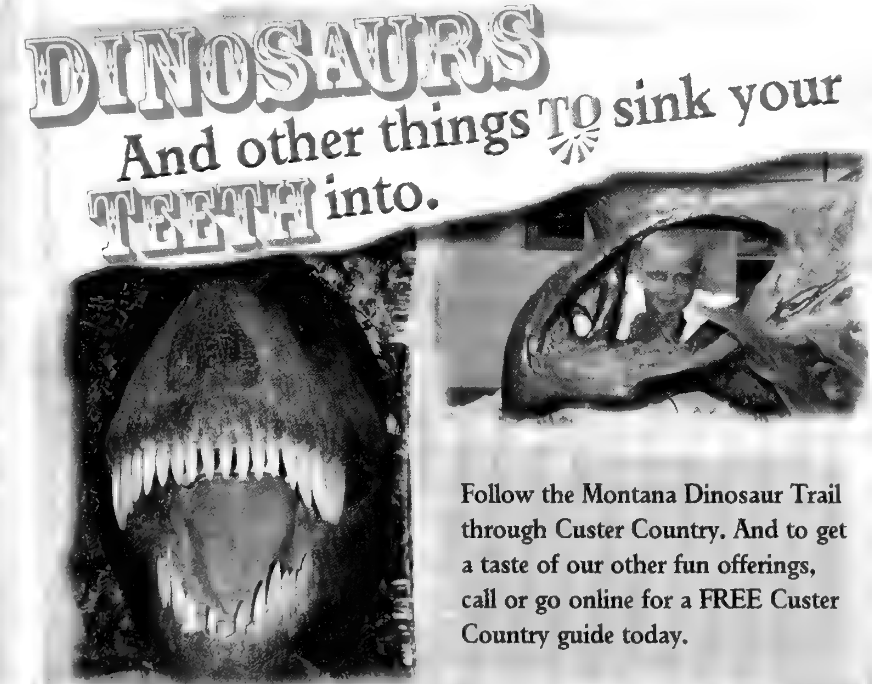
We're also home to Pompeys Pillar (where Capt. William Clark inscribed his name 200 years ago, the only physical evidence left behind by the Lewis and Clark Expedition) and Western lore a-plenty. When it comes to great vacation opportunities, Custer Country should be on the top of your list of places to visit.

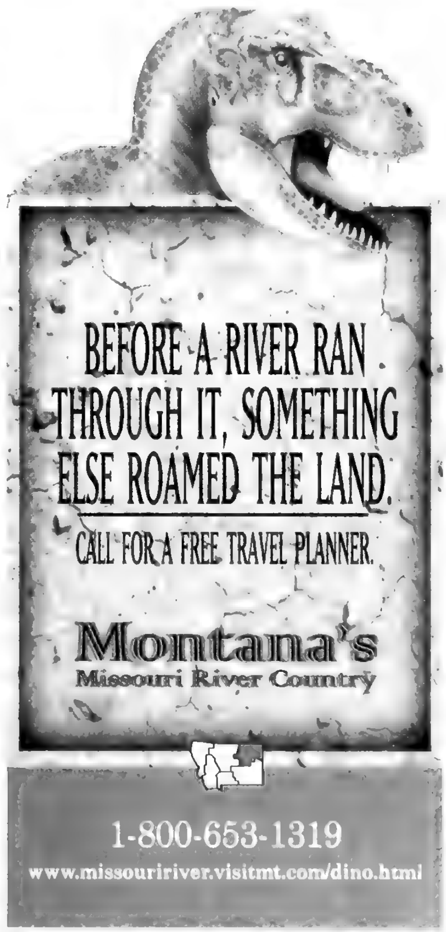
Whether your interest lies in paleontology, biology, photography, or ornithology, you'll find it here in Custer Country. For more information or to order a guide, visit our website at Custer.VisitMT.com or call 1-800-346-1876. For more information about the Montana Dinosaur Trail, go to MTDinotrail.org.


Fort Union

Missouri River Country

MISSOURI RIVER COUNTRY, in the northeastern corner of Montana, has everything from dinosaurs to outlaws. The famous outlaw Kid Curry began his career here. Pioneer Town, located in Scobey, is an entertaining window into the homestead era of the early twentieth century. Standing majestically atop the rolling prairies of eastern Montana, the Fort Peck Theatre—built in 1934 during the Fort Peck Dam construction days—is one of the state's most magnificent treasures. The newly built Fort Peck Dam Interpretive Center features C. M. Russell wildlife exhibits; fossils, including a cast of the *Tyrannosaurus rex* known as Peck's Rex; and displays on dam construction, boomtowns, and homesteading.





CHEROKEE, NORTH CAROLINA

The Cherokee have lived in this area of North Carolina for more than 11,000 years.

DISCOVER 11,000 YEARS OF CULTURE AND adventure in Cherokee, North Carolina, the ancestral homeland of the Cherokee Indians. This sovereign nation in western North Carolina, about 100 square miles wide, is the home of the descendants of those who defied the forced removal to Oklahoma (on the famed Trail of Tears) or returned. These descendants are preserving a culture older than that of Egypt or Greece in the heart of the Great Smoky Mountains.

In Cherokee, you are welcomed by people who proudly preserve a culture far older than the new nation surrounding them.

The Oconaluftee Indian Village replicates the sights and sounds of Cherokee life in 1750. Here you can see pottery being crafted in the ancient Cherokee tradition, intricate baskets handcrafted from oak, blowgun demonstrations, and the creation of brilliant mosaics, one bead at a time. Be there on the opening night of the fifty-seventh season of "Unto These Hills," an outdoor drama that tells the story of the Cherokee (including a recreation of the Eagle Dance), featuring Cherokee actors, authentic Cherokee music using real Cherokee, and use of the Cherokee language. Now updated to present a more culturally accurate version of Cherokee history, the play is performed nightly, except Sundays, at the beautiful Mountain Side Theater, from June 8 to August 19. At the Museum of the Cherokee Indian, the Eastern Band of the Cherokee present themselves and their history according to their own world view. Don't miss the new exhibit "Emissaries of Peace," which features tales of Cherokee encounters and travel abroad. Meet living masters of Cherokee arts as you browse for treasures at Qualla Arts & Crafts, an outstanding Cherokee-owned and operated arts cooperative. Witness the largest gatherings of indigenous tribes in the Southeast in 2006 as the Cherokee Indian Fairgrounds presents the Southeastern Tribes Cultural Arts Celebration, May 19-20, as well as the 2nd Annual Festival of Native Peoples, August 24-25. These weekends promise to be filled with native dance, song, storytelling, authentic foods and art. For more information on cultural events in Cherokee in 2006, please visit the web at www.cherokee-nc.com

All of Cherokee awaits you...with pleasure!

Left to right: The ancient art of fingerweaving is demonstrated daily at the Oconaluftee Indian Village; the infamous Eagle Dance has been performed at "Unto These Hills" for 56 years; Cherokee dwellings from the 1750's are replicated at the Oconaluftee Indian Village

NEW YORK STATE

New York's natural mineral springs and spas have been providing healing, rest and relaxation for more than a century.

WATER THERAPIES, FRESH AIR AND sunlight, diets, botanical medicines, and counseling were some of the naturopathic treatments that flourished in New York State in the 1800s. Not surprisingly, visitors still come to the state for therapeutic treatments, rest, and relaxation, and many flock to the historical spas built around the natural mineral springs in Saratoga Springs, Sharon Springs, and Clifton Springs.

A spa getaway promises pampering, luxury, and fun.

Saratoga Springs, located along New York State's Champlain Canal Scenic Byway, is about three hours north of New York City. It is the second oldest water cure resort in the country (and the oldest in the Northeast). You may still enjoy a soak in the soothing effervescent waters of the historic Roosevelt and Lincoln Mineral Baths and Spa. There are dozens of springs all over Saratoga, and many may be sampled for free; look for them in Congress Park, at the Saratoga Race Course, at Saratoga Spa State Park, and the Iron Spring in Ballston Spa.

Sharon Springs, located along the edge of the Catskill Mountains, was once an internationally famous health resort because of its springs, which are within walking distance from the town. The original bathing buildings from the 1800s, destroyed by a fire, have been replaced with spacious spas. Don't miss the Chalybeate Spring Temple, built in 1910, just a few hundred feet south of the sulfur and magnesia springs. This spring contains iron, and its waters were once bottled and sold for medicinal purposes. The Beaux Arts-style White Sulphur Temple, built in 1927, still offers sulfur water for drinking.

Clifton Springs, a historically pristine town located midway between Geneva and Canandaigua, has numerous springs and its famous sanitarium (now known as a spa) surrounded by a park.

A spa visit nowadays may also include a heated stone massage, loofah scrub, or a seaweed wrap. For more information about the natural mineral springs—and about spa vacations in any part of New York—visit iloveny.com.

Top: Spa reflecting pool, Saratoga; left: Clifton Springs


"Let's get away!"
"Where to?"
"I have a great place in mind."
"Oh? Where?"
"You'll see...I've made all the arrangements."
"All we need is a map."
"So you want to just...go?"
"Yeah...like we used to do...
before kids. Remember?"
"Uh huh...do we dare?"
"What's stopping us?"
"Finding my glasses."
"I have a spare set."
"Want to bring the grandkids?"
"!!!"
"What?"
I ♥ NY
GREAT VACATION
To reconnect,
connect to
iloveny.com, and plan
your great getaway
to New York State!
I ♥ NY
Vacations
iloveny.com
What a great vacation!
George E. Pataki, Governor, New York State
Charles A. Gargano, Chairman, Empire State Development

THE ADIRONDACK REGION

New York State's Adirondack region contains 3,000 ponds and lakes, 2,000 miles of hiking trails, nearly 100 campgrounds and, of course, the Adirondack Mountains.

THE ADIRONDACK PARK, CREATED IN 1892, is as large as the state of Vermont and unique in that it comprises both public and private lands. To explore this region of northern New York, try one of the fourteen scenic driving tours or trails, each with its own theme. The 188-mile Adirondack Trail, from the old Erie Canal near Fonda in the south to the Ballard Mill Center of the Arts in Malone in the north, runs through the core of the Adirondacks, along mountain ponds, wild forest areas, and beautiful lakes. The spectacular 140-mile Central Adirondack Trail begins in Glens Falls, heads northwest through the heart of the Adirondack Mountains, then turns south through dense wilderness to Rome. The 112-mile Southern Adirondack Trail connects the historic Canal town of Herkimer to Lake Pleasant, traversing mountains, lakes, and charming villages along the way. The Black River Trail, 111 miles long, follows the western edge of the Adirondacks, crossing gorges, river valleys, and the Tug Hill Plateau, the area with the highest annual snowfall in the eastern United States. The High Peaks Byway, a 30-mile drive from the Adirondack Northway to Lake Placid, climbs through narrow passes flanked by towering mountains, sparkling streams, waterfalls, and lakes; and the Blue Ridge Road is a scenic 17-mile route connecting North Hudson and Newcomb. For information about the other byways in the region, and to download an interactive map, visit www.adk.com.

Announcing

THE FRANKLIN INSTITUTE *Awards*

Dating back to 1824, The Franklin Institute Awards Program seeks to provide public recognition and encouragement of excellence in science and technology. Since 1874, recipients have been selected by the Institute's Committee on Science and the Arts. Today, fields recognized include Chemistry, Computer and Cognitive Science, Earth and Environmental Science, Engineering, Life Science, and Physics. In 1998, the Awards Program was reorganized under the umbrella of The Benjamin Franklin Medals. The list of medal winners reads like a "Who's Who" in the history of 19th, 20th, and 21st century science. The honor roll includes: Alexander Graham Bell, Marie Curie, Rudolf Diesel, Thomas Edison, Niels Bohr, Max Planck, Albert Einstein, and Stephen Hawking—to name a few. To date, 105 Franklin Institute Laureates also have been honored with 107 Nobel Prizes.

The newest awards, the Bower Award for Business Leadership and the Bower Award and Prize for Achievement in Science, are made possible by a $7.5 million bequest in 1988 from Henry Bower, a Philadelphia chemical manufacturer. The Bower Science Award carries a cash prize of $250,000, one of the richest science prizes in America. The Awards Ceremony is April 27, 2006 in the Benjamin Franklin National Memorial at The Franklin Institute in Philadelphia, PA. More information on the Awards Program can be found at www.fi.edu/franklinawards.

2006 FRANKLIN INSTITUTE LAUREATES

Bower Award and Prize for Achievement in Science
NARAIN G. HINGORANI, Ph.D, D.Sc.
Consultant

For the conceptualization and pioneering advancement of the Flexible AC Transmission System (FACTS) and Custom Power in electric power systems, and for outstanding technical contributions in High Voltage Direct Current Technology, which have enhanced the quality and security of the electric power system.

Dr. Hingorani received his B.Sc. in electrical engineering from Baroda University in India in 1953 and his Ph.D. from the University of Manchester Institute of Science and Technology in 1961. For 20 years, he worked at the Electric Power Research Institute (EPRI) in Palo Alto, California, where for five years he was Vice President, Electrical Systems Division.

Bower Award for Business Leadership
TED TURNER
Philanthropist and Media Entrepreneur

For his visionary leadership in the worlds of business and media, as well as his philanthropic commitment to the health of our planet and the well being of its people.

Media visionary, philanthropist, and sportsman; rancher, environmentalist, and entrepreneur; and most recently, restaurateur—Robert Edward (Ted) Turner III has divided his time among so many passions over the years and made so many public contributions that he has become a household name among Americans.

In addition to his work in the entertainment and broadcast industry, Mr. Turner has made his mark as one of the most influential philanthropists in the nation, donating more than a billion dollars of his own money.

Benjamin Franklin Medal in Computer and Cognitive Science
DONALD A. NORMAN, Ph.D.
Northwestern University
Nielsen Norman Group

For the development of the field of user-centered design, which uses our under-

standing of how people think to develop technologies designed to be easily usable.

After receiving a B.S. in 1957 from M.I.T. and a M.S. in 1959 from the University of Pennsylvania, both degrees in electrical engineering, Dr. Norman switched fields and earned a Ph.D. in psychology in 1962 from the University of Pennsylvania. His diverse academic and work experience gave him a unique perspective on "human information processing."

Benjamin Franklin Medal in Physics
GIACINTO SCOLES, FRS
Princeton University
International School for Advanced Studies, Elettra Synchrotron Laboratory
J. PETER TOENNIES, Ph.D.
University of Göttingen
Max Planck Institute

For the development of new techniques for studying molecules, including unstable species that could not be examined otherwise, by embedding them in extremely small and ultra-cold droplets of helium. Their work also led to a better understanding of the extraordinary properties of superfluid helium, such as its ability to flow without friction.

Giacinto Scoles earned a master's degree from the University of Genoa in 1959, and completed his postdoctoral work at the University of Leiden in The Netherlands. Throughout his academic career, he has divided his time between various institutions. He now teaches at Princeton and the International School for Advanced Studies and conducts research at the Elettra Synchrotron Laboratory.

Peter Toennies was born and raised in the Philadelphia area. He earned a bachelor's degree in physics at Amherst College in 1952 and a Ph.D. from Brown University in 1957. In 1969, he became the director of the Max Planck Institute in Göttingen. He currently works in Göttingen and Bonn and lectures extensively throughout the United States and the world.

Benjamin Franklin Medal in Earth and Environmental Science
LUNA LEOPOLD, Ph.D. (1915-2006)
University of California, Berkeley
M. GORDON WOLMAN, Ph.D.
Johns Hopkins University

For advancing our understanding of how natural and human activities influence landscapes, especially for the first comprehensive explanation of why rivers have different forms and how floodplains develop. Their contributions form the basis of modern water resource management and environmental assessment.

Engineer, meteorologist, geologist, and environmentalist—Luna Leopold wrote the first environmental impact statement on the Everglades that saved that wildlife refuge from sure destruction. Leopold earned a B.S. in civil engineering from the University of Wisconsin, Madison, in 1936 and a Ph.D. in geology from Harvard University in 1950.

M. Gordon Wolman is B. Howell Griswold, Jr. Professor of Geography and International Affairs at Johns Hopkins University. He received his undergraduate degree from Hopkins in 1949 and his M.S. and Ph.D. degrees in geology from Harvard in 1951 and 1953.

Benjamin Franklin Medal in Chemistry
SAMUEL J. DANISHEFSKY, Ph.D.
Columbia University
Memorial Sloan-Kettering Cancer Center

For his achievements in synthetic organic chemistry, particularly for the development of methods for preparing complex substances found in nature and their emerging applications in the field of cancer treatment.

Samuel Danishefsky is recognized as a leader in synthesizing the precise three-dimensional structures of many complex organic compounds, a field that plays a pivotal role in the discovery and development of new pharmaceuticals. He earned his Ph.D. in chemistry at Harvard in 1962 and began his career at the University of Pittsburgh, where he taught until 1979. He has been a professor of chemistry at Columbia University since 1993.

Benjamin Franklin Medal in Life Science
FERNANDO NOTTEBOHM, Ph.D.
The Rockefeller University

For his discovery of neuronal replacement in the adult vertebrate brain and the elaboration of the mechanism and choreography of this phenomenon; and also for showing that neuronal stem cells are the responsible agents, thereby generating a completely new approach to the quest for cures for brain injury and degenerative disease.

Dr. Nottebohm, born in Buenos Aires, Argentina, has spent a lifetime studying songbirds. He earned a B.S. in zoology in 1962, and a Ph.D. in 1966 from the University of California, Berkeley. His entire career has been with The Rockefeller University, where he is now director of the Field Research Center for Ecology and Ethnology in Millbrook, N.Y.

Benjamin Franklin Medal in Civil Engineering
RAY W. CLOUGH, Sc.D.
University of California, Berkeley

For revolutionizing engineering and scientific computation, and engineering design methods through his formulation and development of the finite element method, and for his innovative leadership in applying the method to the field of earthquake engineering with special emphasis on the seismic performance of dams.

Ray Clough graduated from the University of Washington's civil engineering program in 1942 and concluded his graduate studies in structural engineering at M.I.T. in 1949. He points out that earthquake engineering, at that time, was not even a recognized part of any civil engineering curriculum. Ray Clough is credited with developing the Earthquake Research Center in Berkeley, California.

COMMENTARY

Cooking the Climate with Coal

In the U.S., China, and elsewhere coal is booming. But the boom may lead to environmental disaster.

By Jeff Goodell

On a cold morning in February 2005, the school gym at Nashville Community High School in southern Illinois was jammed to the rafters with local residents and kids. More than 2,300 students had been dismissed from morning classes and bused in from around the region. Squads of cheerleaders cartwheeled across the gym floor, while the Nashville Hornets school band filled the gym with rousing songs. "Opportunity Returns," a banner proclaimed, quoting Illinois Governor Rod R. Blagojevich's campaign slogan to bring prosperity back to southern Illinois.

Opportunity was returning in the form of a $2 billion coal-fired power plant, which the world's largest coal company, Peabody Energy Corporation, of St. Louis, was about to build just a few miles southwest of Nashville. According to the governor, the plant, to be known as the Prairie State Energy Campus, would create 2,500 construction jobs, 450 permanent jobs, and $100 million or so a year in spin-off revenues. A phalanx of Peabody executives was on hand to show their support. Peabody's CEO at the time, Irl F. Engelhardt, stepped up to the microphone. "The technology Prairie State will use is absolutely the best that has been put together

on a coal plant," Engelhardt assured the crowd. "Prairie State is an important step forward in terms of the cleanliness of coal plants, and ultimately will help us get to near-zero emissions from coal plants."

A few local politicians chimed in, the band struck up the Hornets' fight song, and there was a lot of clapping and backslapping. Even the kids in the bleachers, most of them born long after the coal industry had died in the region, were on their feet cheering. "Coal is U.S.A.!" someone shouted. "Coal is U.S.A.!"

For Big Coal—the alliance of coal mining companies, utilities, railroads, and lobbying groups that make coal such a powerful political and economic force in America—the slogan "Opportunity Returns" is a rather coy understatement. "Boom" is more like it: the world is in the midst of an unprecedented love affair with coal. According to the International Energy Agency (IEA), the energy equivalent of some 1,350 thousand-megawatt coal-fired power plants will be built by 2030. Forty percent of them will be in China, where coal is fueling a stunning economic transformation. India will add another 10 percent or so, and most of the remaining half will be added in the West. In the United States, the IEA predicts, about a third of the new electric-generating capacity built by 2025 will be coal-fired. Besides Peabody's Prairie State plant, more than 120 new coal plants are now in the works throughout the nation.

Many people think coal in the U.S. went the way of top hats and corsets. In fact, the U.S. depends more on coal today than ever before. Americans consume, on average, about twenty pounds of it a day. Roughly half the nation's electricity comes from coal—more than a billion tons of it a year. In fact, electric-power generation is one of the largest and most capital-intensive industries in the country, with revenues of more than $260 billion in 2004 alone. Americans may not like to admit it, but the nation's shiny white iPod economy is propped up by dirty black rocks.

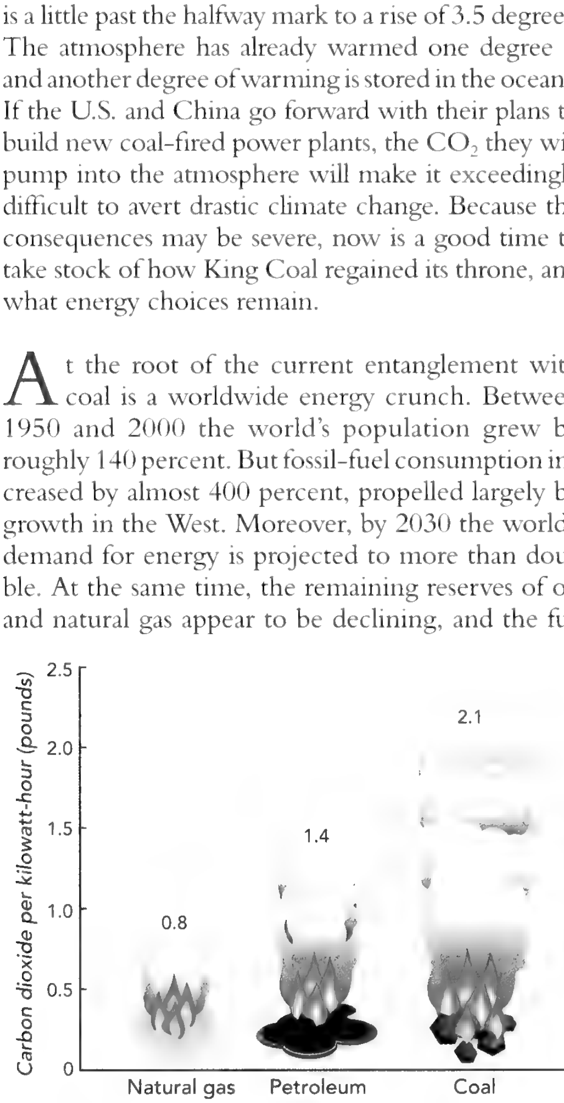
Yet coal harbors some profound character flaws, and all nations—but particularly the U.S. and China—ought to consider them carefully before transforming their whirlwind infatuation with the economics of energy from coal into a long-term commitment. First, coal can be quite dangerous to acquire. For proof, one need look no further back than this past January, when twelve men died after an explosion at West Virginia's Sago Mine, or to later that month, when two more miners died in a fire in West Virginia's Alma Mine. A few weeks later, sixty-five miners were trapped and killed after an explosion at a Mexican mine. China's coal mines are even more notorious death traps: some 6,000 workers are killed there each year.

Furthermore, coal damages the environment and public health. Mining it levels mountains and disrupts ecosystems. Burning it yields toxic emissions that cause acid rain, polluted lakes and rivers, and poor air quality. Perhaps most important, burning it emits far more carbon dioxide (CO_2) per unit of usable energy output than any other energy source. Carbon dioxide, of

Conveyor belt lifts coal out of Peabody Energy's Gateway Mine in southern Illinois. Coal and coal mining have recently enjoyed a tremendous resurgence, despite the negative effects of coal-fired power plants on global climate.

course, is a potent greenhouse gas; the more CO_2 in the atmosphere, the warmer the Earth gets. In 2005, at a conference in Exeter, England, on the dangers of abrupt climate change, 200 leading climatogists and policy makers from thirty countries agreed that if the Earth's average surface temperature should rise above pre-industrial levels by more than 3.5 degrees Fahrenheit (about two degrees Celsius), the risk of dangerous climate change would increase dramatically. The consequences of such change have been well documented and publicized: among them are higher sea levels, more intense storms, local desertification, and rapid disruption of ecosystems. Right now the Earth is a little past the halfway mark to a rise of 3.5 degrees. The atmosphere has already warmed one degree F, and another degree of warming is stored in the oceans. If the U.S. and China go forward with their plans to build new coal-fired power plants, the CO_2 they will pump into the atmosphere will make it exceedingly difficult to avert drastic climate change. Because the consequences may be severe, now is a good time to take stock of how King Coal regained its throne, and what energy choices remain.

At the root of the current entanglement with coal is a worldwide energy crunch. Between 1950 and 2000 the world's population grew by roughly 140 percent. But fossil-fuel consumption increased by almost 400 percent, propelled largely by growth in the West. Moreover, by 2030 the world's demand for energy is projected to more than double. At the same time, the remaining reserves of oil and natural gas appear to be declining, and the future of nuclear power and renewable energy (solar power, wind power, and the like) remains uncertain. By default, then, coal has emerged as the fuel of choice. Indeed, as oil prices climbed above sixty dollars a barrel last year, a long-dormant interest was renewed in building plants that can transform coal into diesel and other liquid fuels—an expensive, inefficient process that releases large quantities of CO_2.



Source: Natural Resources Defense Council, from data provided by the U.S. Energy Information Administration

Amount of carbon dioxide (CO_2), an important greenhouse gas, that is emitted into the atmosphere per unit of electrical energy produced is plotted for three fossil fuels. Burning coal emits more CO_2 per unit energy than any other fuel. Nuclear power, as well as hydroelectric and other renewable sources, emits little or no CO_2.

Of course, coal also has a number of virtues: it can be transported by ship and rail, it's easy to store, and it's easy to burn. But its main advantage over other fuels is that it is cheap and plentiful. The Earth still harbors an estimated 1 trillion tons of recoverable coal, by far the largest reserve of fossil fuel left. And the U.S. has the geological good fortune to have more than a quarter of it—about 270 billion tons—buried within its borders. As coal boosters never tire of pointing out, the coal in U.S. ground is enough to fuel the nation's electricity needs, at the current rate of consumption, for 250 years. China has less than half as much as the U.S.—126 billion tons. But that amount will keep China's lights on for about seventy-five years if consumption stays at its current rate.

In addition to those considerable advantages, several recent historical factors have also contributed to the coal boom in the U.S. California's rolling blackouts in January 2001 underscored the need for new investment in electricity generation and transmission. The collapse of Enron helped throw the natural-gas market into turmoil, sending prices skyrocketing and making coal extremely cheap by comparison. The 2000 presidential election was another turning point. Coal-industry executives knew that if the Democratic candidate, Al Gore, were elected, regulations to limit or tax CO_2 emissions would soon follow. So Big Coal threw its money and muscle behind George W. Bush. President Bush reciprocated by staffing regulatory agencies with former coal-industry executives and lobbyists, and by inviting Big Coal to play a prominent role in crafting the nation's new, unabashedly coal-friendly energy policy. Finally, the terrorist attacks of September 11, 2001, made many people reconsider the high cost of depending on oil from the Middle East.

What's most remarkable about America's current coal boom is that, unlike other recent booms, which were driven by a (perhaps irrational) exuberance, this one is driven by overwhelming fear: fear that the world is running out of energy, fear that the U.S. is losing its edge, and, most of all, fear that if Americans don't burn more coal, not only the economic health of the nation but civilization itself is at risk. "Have you ever been in a blackout?" one coal executive asked me. "Do you remember how dark the whole world gets? Do you remember how scary it is?"

Mountaintop-removal mines, such as this one in southeastern West Virginia, have destroyed more than 700 miles of streams and at least 400,000 acres of forest throughout Appalachia. Workers blast away the uppermost 800 to 1,000 feet of rock to expose layers of coal within, dumping rocky debris into nearby valleys and streams. Local residents often suffer noise, dust, polluted groundwater and rivers, flooding, and lowered property values. Once such mines close, they are replanted with grasses and trees, then left to regenerate as wilderness; some have been developed as golf courses, factories, or other facilities.

Big Coal frequently argues that today's coal boom is not like coal booms of the past. And in some ways, that's true. Mining practices in some regions have vastly improved, and the industry is safer than it was thirty years ago. Emissions of sulfur dioxide and nitrogen dioxide at new coal plants are much lower than they are at old plants. "Increasingly clean" is the industry's favorite sound bite.

But the truth of the phrase leans heavily on the word "increasingly." The scrubbers on new coal plants might be better, but the plants still release plenty of arsenic, cadmium, lead, mercury, sulfur dioxide, and soot particles. They still require prodigious amounts of water for cooling, and generate millions of tons of coal ash, laden with heavy metals. Nor does "increasingly clean" exactly describe the mountains of Appalachia being blasted away to supply the fuel for the new plants. Mountaintop-removal mining, as this practice is called, is a recent innovation.

And many of the new coal plants are much like earlier generations of plants in one crucial way: they, too, discharge hundreds of millions of tons of CO_2 into the atmosphere. Prairie State, for instance, will emit more than 11 million tons of CO_2 a year, only marginally less than a plant of similar size built thirty years ago. That is why the coal boom is so alarming.

Right now about one quarter of the world's CO_2 emissions come from coal-burning power plants; all the world's uses of coal together account for about 40 percent of emitted CO_2. The 1,350 gigawatts of new coal-fired generating capacity projected for construction in the next twenty-four years will, if built, add roughly 572 billion tons of CO_2 to the atmosphere during the new plants' sixty-year operating lives. That is about as much CO_2 as was released by all the coal burned by everyone, for every purpose, during the past 250 years. Adding that much CO_2 to the atmosphere will make it much harder to limit global warming to the relatively "safe" increase of 3.5 degrees F.

Ironically—though many in the coal industry deny the reality of climate change—global warming poses the biggest threat to the hegemony of cheap coal. Almost everyone in the industry acknowledges that in the next decade or so, laws that cap CO_2 emissions will be passed in the U.S. So, in a perverse way, it is precisely the likelihood of new laws that is fueling the current mad dash to throw up coal plants. The reasoning goes like this: If new plants aren't approved and built before power companies are forced to pay for releasing CO_2, energy costs will go up, and coal plants will be underbid by wind turbines, natural gas plants, and other ways of generating electricity that have less carbon liability. What's going on now is not exactly a land grab—it's an atmosphere grab.

"Cheap" coal also wouldn't seem such a bargain if its numerous hidden costs were calculated into the price of power rather than off-loaded onto the public, as they now are. Those costs include the blighted

mountains and economic ruin of many coal-mining regions, the medical bills for treating the heart attacks and asthma caused by air pollution, the lost future incomes of children adversely affected because they were exposed in the womb to mercury from fish eaten by their mothers. Using data from a widely respected ten-year study by the European Commission, Robert H. Williams, a physicist at Princeton University, estimates that the effects of air pollution from U.S. coal plants on public health would add about thirteen dollars, or 25 percent, per megawatt-hour to the price of coal-fired energy. For the oldest, dirtiest plants, the added costs could reach thirty-three dollars. In comparison, the cost of such "externalities" for a natural-gas plant is only about forty cents. In a market that accurately reflected true energy costs, coal would not be such an attractive option.

Water and pulverized coal are formed into cakes at a farm in China's southern province of Guangdong. Residents of cities and rural areas alike burn the cakes for cooking and heating.

There is a better way to take advantage of coal's abundance: a relatively new technology that goes by the unfortunately complicated name of integrated gasification combined cycle, or IGCC. Instead of burning coal directly, as conventional coal plants do, IGCC plants cook off major impurities as they convert coal into a synthetic gas, which is then burned to generate electricity. IGCC plants burn nearly as cleanly as natural-gas plants, are 10 percent more efficient than conventional coal plants, consume 40 percent less water, and produce half as much ash and solid waste.

But more important, it is far easier and cheaper to remove CO_2 from coal at an IGCC plant—because CO_2 is concentrated during gasification—than it is at a conventional coal plant. The CO_2 could then be sequestered underground or perhaps under the sea. Carbon dioxide sequestration is still a controversial idea that is just beginning to be tested. But the combination of IGCC technology and CO_2 capture and sequestration at least offers a plausible way to continue burning coal without trashing the climate.

Out of the hundred or so coal-powered plants slated for construction in the U.S., however, only a handful are now planning to incorporate IGCC technology. Why? First, Big Coal argues, the plants are expensive: an IGCC plant costs between 10 and 20 percent more to build than a conventional coal plant does. That may be true, but if you factor in the likelihood of future limits on CO_2 emissions, the advantages of carbon capture and sequestration would enable IGCC to operate more cheaply by nearly 20 percent. In the long run, electricity from IGCC plants will almost certainly be cheaper than electricity from conventional coal plants.

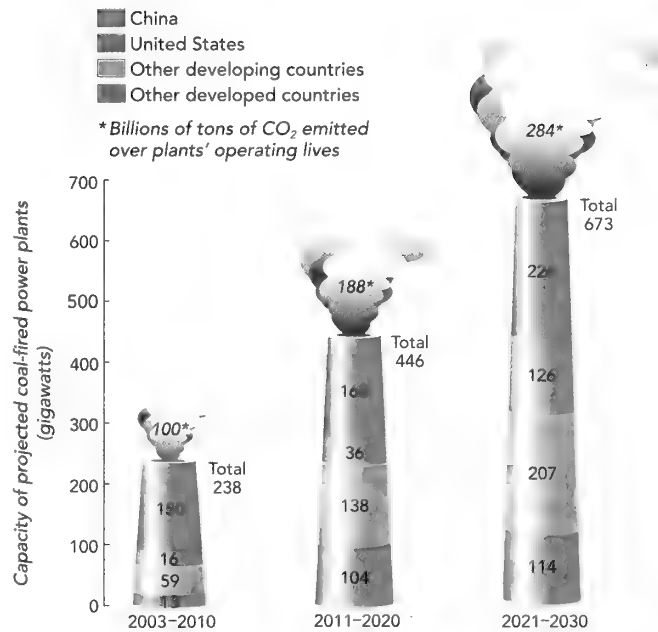
Second, Big Coal asserts, IGCC is still an unproven technology. Yet engineers have been gasifying coal for 150 years, and coal-gasification plants in the U.S. and elsewhere have been generating electric power since 1984. Some of the biggest names in power-plant engineering—General Electric Company, the Shell Group, Bechtel Corporation—are starting to promote IGCC. But Big Coal has been pushing instead for one more generation of old combustion plants, rebranded as "clean" by bolting on some new scrubbers.

In China, coal is everywhere. It's piled up on sidewalks, pressed into bricks, and stacked near the back doors of homes. It's stockpiled into small mountains in open fields, and carted around behind bicycles and old wheezing locomotives. Plumes of coal smoke rise from rusty stacks on every urban horizon. Soot covers every windowsill and rings the collar of every white shirt. The Chinese burn less coal per capita than Americans do, but in sheer tonnage, they burn twice

as much. Coal is what's fueling China's economic boom: 70 percent of the nation's energy comes from coal, and Chinese leaders have made it clear that economic growth is their number one priority.

The cost of China's replay of the western Industrial Revolution is obvious. The World Health Organization estimates that in East Asia (predominantly China and South Korea) 355,000 people a year die from the effects of urban outdoor air pollution. All over China, limestone buildings are dissolving in the acidic air, and acid rain is falling on a third of the country, crippling agricultural production. Not surprisingly, pollution is becoming a focus of political unrest.

The CO_2 released by China's ravenous consumption of coal poses a grave threat—not just within China's borders but to the entire world. The Kyoto Protocol, now ratified by 162 nations (though, notably, not by the U.S. and Australia), calls for cutting greenhouse-gas emissions by 5.2 percent from 1990 levels by 2012. The coal-fired power plants that China plans to build by 2012 will generate more than twice that amount of greenhouse gases (as a developing nation, China need not reduce its emissions even though it ratified the treaty). By 2025, if China continues down its current path, it will overtake the U.S. as the world's largest greenhouse-gas polluter—and the chances of avoiding drastic climate change will become virtually zero.



Source: Natural Resources Defense Council, from forecasts by the U.S. Energy Information Administration and the International Energy Agency

Projected new coal-fired generating capacity is shown. The total capacity is the equivalent of 1,357 new thousand-megawatt plants, which would emit more CO_2 over their operating lives—572 billion tons—than all the CO_2 emitted by all human coal burning before 2003.

In spite of such dire projections, China has done a lot to clean up its act. It has banned the use of coal for heating and cooking in cities such as Beijing and Shanghai; it has moved coal-fired power plants out of urban areas and replaced them with plants that burn natural gas; it has tightened energy-efficiency requirements on new buildings; and it is building one of the world's largest offshore wind farms. In some ways, China has already leapfrogged ahead of the U.S. In 2005 the Chinese government announced that by 2020, renewable sources would generate 15 percent of the country's energy. Whether that prediction is an aspiration or a firm commitment remains to be seen, but in 2005 a similar provision was stripped out of the U.S. energy bill. China also has passed vehicle fuel-efficiency standards that are much stricter than the ones in the U.S. But even with all those measures, China still has a long way to go.

The world faces two enormous challenges in the coming years: the end of cheap oil and the arrival of global warming. Coal may provide a solution to the first challenge, but only by exacerbating the second. Any serious effort to address global warming must target greenhouse-gas emissions by coal-powered plants, particularly in the U.S. and China. Americans can argue about the best way to do this—ratify the Kyoto treaty and persuade China to adopt its emissions limits, tax CO_2 emissions, provide bigger subsidies to clean-power development, mandate that new coal plants use IGCC technology and carbon sequestration, or give away free bicycles—but do it we must.

The biggest impediment to such changes is the idea that Americans are dependent on the very thing that is killing us. That claim is made all the time: Passing laws that limit CO_2 emissions, or require cleaning up dirty coal plants, or restrict mountaintop-removal mining, it is argued, will cause the price of electricity to skyrocket and the economy to collapse. And it is true that reforming the industry could cause electricity prices to rise, and bring genuine economic hardship to some areas. But the costs and consequences of global warming are simply too high to continue the indulgence in cheap coal.

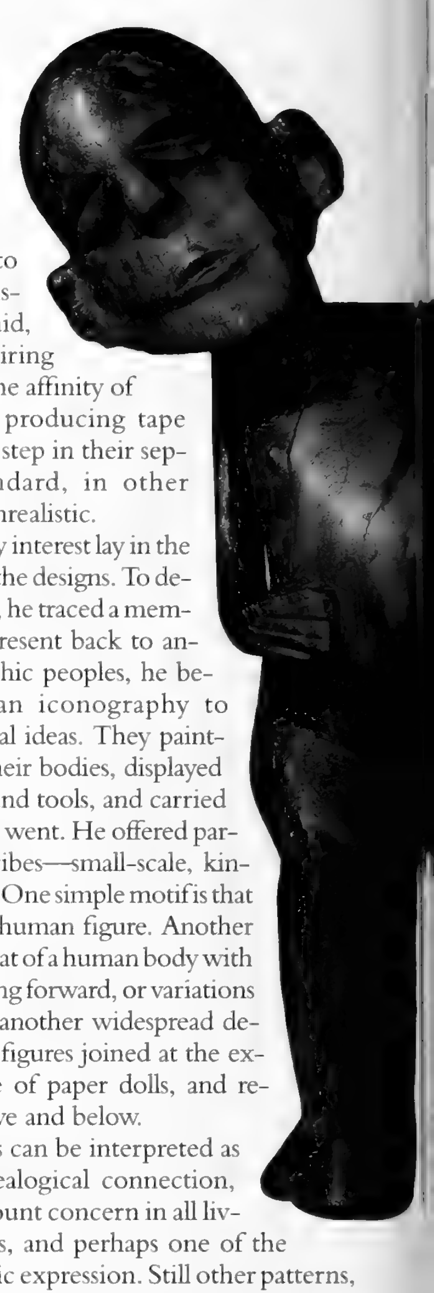
Blind faith in technology is unwarranted; but people can certainly figure out less destructive ways to create and consume the energy the world needs. Ultimately, the most valuable fuel for the future is not coal or oil, but imagination and ingenuity. □

This article was adapted from Big Coal: The Dirty Secret Behind America's Energy Future, *by Jeff Goodell, which is being published in June by Houghton Mifflin Company.*

Decoding the Tribe

Carl Schuster's remarkable quest to trace humanity's ancient iconography

By Edmund Carpenter



I first met Carl Schuster in the late 1950s. I was living in desert California, with no phone and few visitors. He simply appeared at my door: "I understand you're just back from Irkutsk."

Archaeology—nothing else—had taken me to Siberia. But in those Cold War years, who would have believed that? And who was this stranger? I determined he wasn't getting past the screen door!

My visitor spoke of his own research and mentioned photographs in his car. I thought it might be easier to get rid of him from there. The first photograph showed an incised stone. He said it came from California. I corrected him: Spain. Yet the back of the photograph documented its California origin. He showed me more. I suggested we go inside, out of the sun.

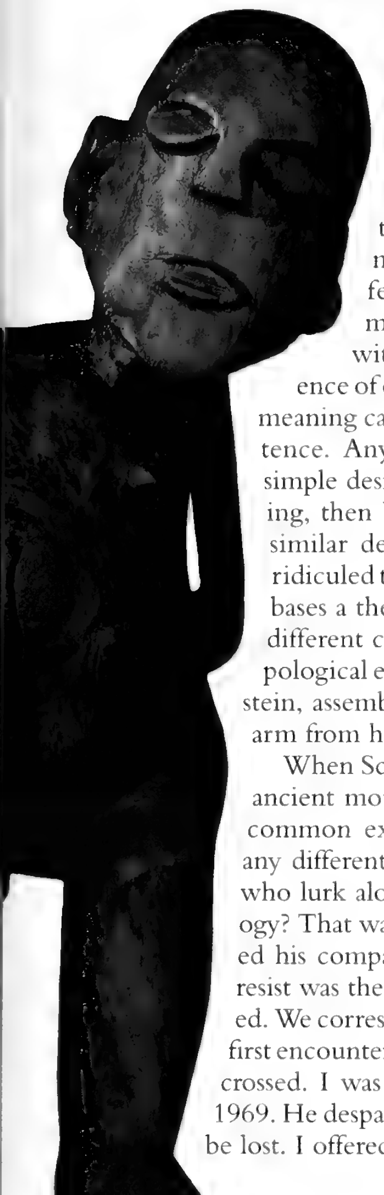
There Schuster juxtaposed various images of objects spanning 30,000 years; they exhibited strikingly similar designs. He made no claim to have documented historical connections among them, but the internal testimony of the designs themselves, he proposed, pointed to common symbolic origins. Such evidence flew in the face of scholarly assumptions about cultural history. But to demand proof of historical contact, he said, would be like requiring a linguist to prove the affinity of two languages by producing tape recordings for each step in their separation. The standard, in other words, would be unrealistic.

Schuster's primary interest lay in the intelligence behind the designs. To decode the symbolism, he traced a memory line from the present back to ancient times. Paleolithic peoples, he believed, invented an iconography to illustrate genealogical ideas. They painted the designs on their bodies, displayed them on garments and tools, and carried them wherever they went. He offered parallels with recent tribes—small-scale, kinship-based societies. One simple motif is that of an upside-down human figure. Another recurring image is that of a human body with two heads, both facing forward, or variations on that theme. Yet another widespread design depicts human figures joined at the extremities, suggestive of paper dolls, and repeated in ranks above and below.

All those patterns can be interpreted as expressions of genealogical connection, or kinship, a paramount concern in all living human societies, and perhaps one of the first to elicit symbolic expression. Still other patterns,

Figurines depicting one body with two forward-facing heads have been made in many places at many times: Eastern Europe, ca. 4000 B.C. (left); Tahiti, nineteenth century (above right); and Mesoamerica, ca. 900–500 B.C. (opposite page at upper right). One interpretation is that they represent a common tradition, dating from Late Paleolithic times as long ago as 30,000 years, of representing a person's genealogical connection to both the mother and the father and, by extension, to their respective kin groups within the tribe. The principal joints (shoulders, elbows, and so forth) in the European figurine are pierced, which serves to mark them; the marking of joints is a common device that often seems to represent ancestors and descendants.

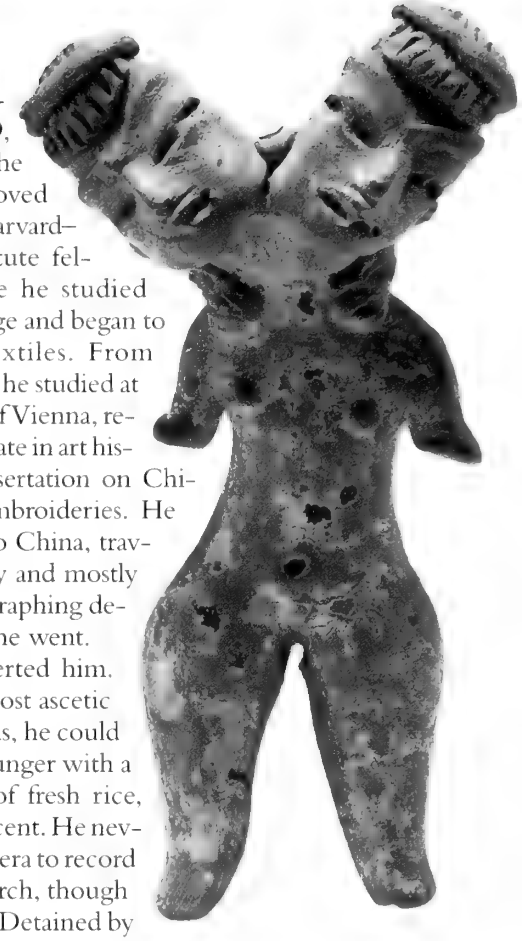
such as various labyrinths, ladders, and game boards, may relate to the progress of a human soul toward an afterlife or rebirth. Those, too, may reflect an extension of genealogical thinking, for the afterlife is often regarded as the realm of the ancestors.



Anthropologists have been burned so often by such ambitious attempts to draw far-flung connections that students are trained to be leery of them, to say the least. A symbol can mean different things at different times and places. Its meaning can even change within one culture in the presence of other symbols, just as a word's meaning can shift from sentence to sentence. Any enthusiast who chooses a simple design, assigns it a single meaning, then bestows that meaning on all similar designs, is more likely to be ridiculed than respected. A person who bases a theory on bits and pieces from different cultures becomes the anthropological equivalent of Victor Frankenstein, assembling a monster by taking an arm from here, an ear from there.

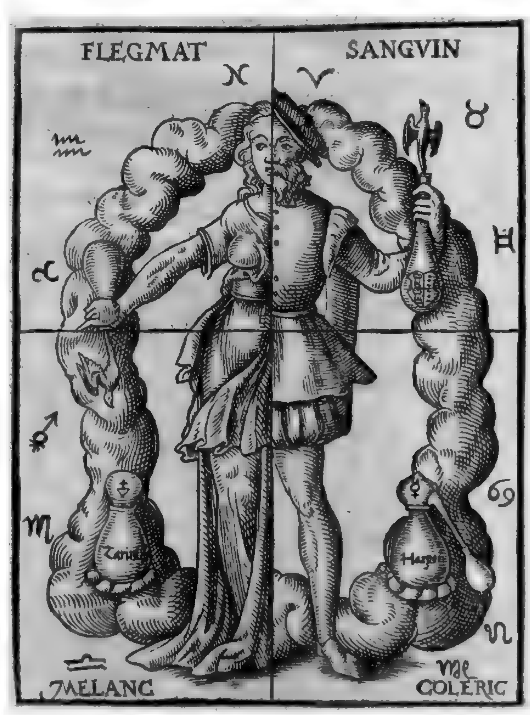
When Schuster juxtaposed recent and ancient motifs, then assigned to them a common explanation, what made him any different from the many "nut cases" who lurk along the fringes of anthropology? That was my initial reaction. I resisted his comparisons. But what I couldn't resist was the evidence. Gradually I yielded. We corresponded for ten years after our first encounter, and met wherever our paths crossed. I was with him when he died in 1969. He despaired that his life's work would be lost. I offered to see it to completion.

Born to a prosperous Milwaukee family in 1904, Carl Schuster attended Phillips Exeter Academy and earned bachelor's and master's degrees from Harvard University. The family fortune vaporized in 1929, however, and the young Carl moved to China on a Harvard–Yenching Institute fellowship, where he studied Chinese language and began to collect folk textiles. From 1933 until 1934 he studied at the University of Vienna, receiving a doctorate in art history with a dissertation on Chinese peasant embroideries. He then returned to China, traveling extensively and mostly on foot, photographing designs wherever he went.



Nothing diverted him. He lived an almost ascetic life. In rural areas, he could readily satisfy hunger with a heaping bowl of fresh rice, which cost one cent. He never raised his camera to record Mao's Long March, though he witnessed it. Detained by Japanese soldiers in rural China, he recorded the event merely to explain why certain notes and negatives were missing. He literally walked through famine, revolution, and war.

Back in America during the Second World War, Schuster worked briefly as a cryptanalyst for the Office of Strate-



German astrological diagram from the late Middle Ages (right) portrays a figure divided into male and female halves, possibly conserving a tribal genealogical motif. The representation is overlain with additional, contemporary meaning. The twelve signs of the zodiac are distributed around the central figure, and a line across the navel further subdivides the figure into four parts, each associated with one of the four temperaments ascribed to the "humors" of the body: black bile, blood, phlegm, and yellow bile.

gic Services (OSS), then returned to research. The American Museum of Natural History provided him with a desk, and in 1945 mounted a major exhibition of his photographs. Then, for the rest of his life, he journeyed, again and again, around the world. A tiny cabin and vegetable garden near Woodstock, New York, served as home base. "I live like a hermit," he noted, "and know only two people, besides shopkeepers, in my small community." Yet he remained connected to the rest of the world through travel and correspondence. He probably spent more on stamps than on food.

Schuster's correspondence file, which with the rest of his archive is now housed in the Museum of Ethnology in Basel, Switzerland, includes more than 18,000 information-packed pages, which he typed single-spaced with narrow margins. Most of his correspondents were leading scholars, but others were self-trained, living in remote areas, who had never shared their work until Schuster arrived. Long after his death, letters from isolated places continued to arrive, filled with data, drawings, and photographs.

Schuster may sound like a classic amateur, a dilettante, but he never wandered aimlessly. He deduced where evidence was likely to be, wrote endless letters, then went directly to the museum, village, or person he had identified. For example, he knew every ethnographic specimen, including two painted robes of immense historical value, that was stored—along with dried food, trade goods, and used nails—in a shed on an isolated ranch in Patagonia. Little escaped him. On one occasion, he tracked down a retired physician in France who, as a medical officer with the Foreign Legion in North Africa, had recorded tattoos on prostitutes and prisoners there and carefully annotated each sketch.

One of the last specimens he photographed was a stone bead discovered by an amateur archaeologist in the Nevada desert. That a collector had spotted such a small, crude object exposed by the wind on a dune in the Humboldt Sink—and recognized it as a human artifact—is astonishing. That Schuster almost immediately found the collector is equally astonishing, but typical.

Behind this lifelong search was pure will, betrayed at the end only by health. "I came to the brink of a very steep downgrade," he recorded when traveling in the Southwest, shortly before his death, "and knowing my physical disability at the time (I was having heart trouble and unable to walk even a few steps without getting out of breath), I felt unwilling to risk that slope in a desert where I could not have expected help from any passers-by."

In ancient iconography similar forms appear again and again across wide regions. Presumably, they once had meanings. Yet the scholarly consensus is that those meanings cannot be recovered. Schuster doubted this. He believed answers survived among living tribal peoples. Nevertheless, he shunned controversy:

> I avoid discussions of principles and devote my energy to building up a picture of the world as it is, by looking at it, instead of arguing about it, and drawing inferences from what I see.

Female figurines from an early nineteenth-century Eskimo grave in the central Canadian Arctic (left) and from the 22,000-year-old Siberian archaeological site of Malta (right) were both pierced for hanging upside down. Such inversion may have symbolized death, indicating that the person portrayed was an ancestor.

Of the many "puzzling parallels" Schuster documented, one of the simplest was the inverted figure [*see photographs at left*]. Many Paleolithic "Venus" figurines, some made as early as 30,000 years ago, were perforated at their ankles so that they could be suspended upside down. From that ancient beginning the practice continued for millennia in several parts of the world, particularly in the Arctic, where it survived into the nineteenth century, and in Oceania, until well into the twentieth. The significance in Paleolithic times of inverting a figure is surely lost to us, who live so much later in time. Or is it? Until recently, certain tribes in the interior of Borneo made entire necklaces of inverted female figures. Their carvers identified the figures as ancestors. And why were they inverted? Inversion, explained the carvers, symbolized death.

Examples of such symbolic reversal delight the so-called structural anthropologists, who seek to tease out the logic behind symbols. Preeminent among

Symbolic labyrinth, like the two-headed figure, occurs as a standardized form in widely divergent places and times: at an archaeological site in western India, ca. 3000–4000 B.C. (above); on a rock face in Cornwall, England, ca. 1500 B.C. (top right); and on a coin from Crete, ca. 280 B.C. (right). When the design is properly drawn, a single, continuous path connects the outside and the center, with no possibility of getting "lost." (In the Greek legend of the labyrinth and the Minotaur, Ariadne gives Theseus a thread so that he can find his way back out, but that should not have been necessary.) The labyrinth may represent a pathway for the spirit to the realm of the ancestors, where it may achieve rebirth.

those scholars is the French anthropologist Claude Lévi-Strauss, professor emeritus of Social Anthropology at the Collège de France, who from his lifelong study of myths and rituals, has hypothesized that the mind—and ultimately the brain—unconsciously understands the world in terms of binary opposites. "If social anthropologists were half as interested in material culture as they ought to be," wrote Lévi-Strauss, with reference to physical artifacts, "they would probably have paid more attention to Carl Schuster's fascinating survey."

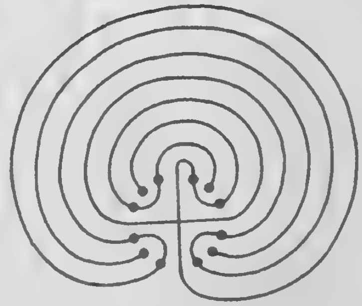
Few have. Part of the problem lies in the excesses of some popular theorists. Anthropologists have (rightly, I think) turned their backs on *The Golden Bough*, first published 1890 by the Scottish anthropologist Sir James George Frazer. Frazer's sweeping attempt to define a common mythical element in religions around the world stripped them of their individuality. The German ethnographer Adolf Bastian's belief that certain elemental ideas developed in disparate places because of the "psychic unity of mankind" had few takers among social scientists. The same fate befell the innate "archetypes of the unconscious," proposed by the early twentieth-century Swiss psychologist Carl Gustav Jung.

Such interpretations of symbolic meaning may be more a projection of a theorist's mind than a reflection of native intention. In contrast, to interpret tribal designs, Schuster drew on his experiences as a cryptanalyst. Decoding, he knew, was easier if you had some idea of what was being transmitted. To decode ancient designs, he turned to native artists. Instead of investigating *how* natives think—as did the French philosopher, psychologist, and ethnologist Lucien Lévy-Bruhl, in works such as *Mental Functions in Primitive Societies* (1910)—Schuster asked the natives directly, "*What* do you think?"

A motif that appears frequently in Schuster's archives is a human figure vertically split into male and female halves (usually its right side is male, its left, female). One common version is simply a single body with the two heads, both facing forward, the sex not necessarily distinguishable [*see photographs on pages 42 and 43*]. In more elaborate examples, the two-headed figure bears a human face or eye at each of its twelve primary joints: shoulders, elbows, wrists, hips, knees, and ankles.

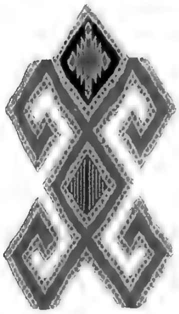
When he encountered contemporary examples of

Sketching a Labyrinth



One way to draw a standard labyrinth, a deceptively simple design, is to begin with an array of twelve points placed around a cross. Two lines, crossing at the center, wall off the pathway; each line has two end points.

the form, Schuster could ask the carvers he visited what they had had in mind when they fashioned a figure that was half male, half female. Such figures appear to have served as social diagrams: the male



Indonesian shroud, woven by the Toraja of Sulawesi Island in the nineteenth century, incorporated a pattern of repeating, interconnected figures that suggest abstract human forms (left). Such patterns appear to represent genealogical descent and ancestry, depending on whether they are read "down" or "up."

half represented the owner's connection with the father and, by extension, the father's social group; the female half represented a similar connection with the owner's mother. Thus the vertical split symbolizes the division of the tribe into two halves, or moieties, as anthropologists call them, a common tribal configuration. The significance of the symbolism comes from the fact that, in many tribal groups, the prescribed form of marriage was between members of two distinct moieties—marriage between a man and woman from the same moiety, the same subdivision, was considered incestuous.

Schuster found that underlying that symbolism was the notion of opposites united in one, as well as the concept of many within one. Such logic is alien to contemporary Western thinking, which takes the individual as the basic unit of society, but in the context of tribalism, it made perfect sense: begin with the whole, and then distinguish the particular. As for the face or eye at the joints, they, too, symbolize the tribe: the upper ones represent ancestors; the ones below the navel, descendants.

Examples of the same designs, ultimately dating back to Late Paleolithic times, have appeared on all inhabited continents. A few survived even in Western civilization, albeit overlain with a more restrictive meaning. Fourteenth-century German manuscripts of the *Sachsenspiegel* ("Mirror of the Saxons"), a collection of customary laws compiled earlier, include a diagram of the human figure that enabled the largely illiterate people of the day to visualize the family relationships relevant for disputes over inheritance. Several German astrological diagrams from the fifteenth and sixteenth centuries show a figure divided down its center into male and female halves, with the twelve symbols of the zodiac distributed around the twelve primary joints [*see illustration at bottom right on page 43*].

Another genealogical motif Schuster documented is the portrayal of reproduction as the budding off of a child from a woman's (or less often, a man's) limb, particularly the knee. Thus, in traditional tribal thought the expression of genealogical descent or relationship does not hinge on an understanding of the biology of procreation.

Perhaps the most important of Schuster's insights concerned certain widespread graphic patterns, ranging from realistic to highly stylized portrayals, which could be interpreted as linked human figures [*see photograph above and images on opposite page*]. Each figure in such patterns is linked diagonally, through fused limbs, to neighboring figures above and below. Of course, continuous limbs may make no sense anatomically, but in Schuster's view, they well represented the puzzle of procreation, which has neither beginning nor end. The ranks above a particular figure, he believed, represented that figure's ancestors, whereas the ones below represented descendants. The device of fused limbs also reflects the fiction of procreation by budding, along with the implied genetic potency of the limbs.

When read from the top down, such a genealogical pattern illustrates descent. Read upward, the same pattern makes it possible for tribal members to retrace their ancestry back to the founding ancestor. Doing so, at least in the traditional way of thinking, guarantees rebirth. In most tribal societies, people have believed in rebirth, not resurrection.

In Schuster's view, many simple geometric designs—repeated chevrons, for instance—are related to the linked-figure patterns. Such simple designs lend themselves to being painted or even incised or

tattooed on the human body, enabling the members of a tribe to mark their commonality. More elaborate tracings, such as a widespread traditional labyrinth design [*see photographs on page 45*], as well as games such as pachisi, snakes and ladders, hopscotch, and chess, may be variations of the genealogical patterns. Not only do they all involve "getting from here to there"; they also often share subtle graphic elements.

I am convinced that Schuster's work bears witness to the survival of an ancient iconographic system. Its earliest known expressions appeared in Europe 30,000 years ago. It crossed continents. Artistic styles illustrating the various genealogical concepts came and went. Cultures sheltered the iconic system without changing it; it outlived most of them. American anthropologists may belittle such expressive parallels as "curiosities." In rejoinder, it is worth recalling that the first Neanderthal skullcap, discovered in 1856, was placed in a curiosity cabinet—and probably would still be there were it not for Darwin's *Origin of Species.*

I asked Schuster what it all meant; he was reluctant to say. Someone gave him a tape recorder; he never used it. His quest was in the search itself. The day before he died—too ill to eat—he mailed funds to a missionary in Panama, asking him to photograph a ladder crafted in anthropomorphic form, located in a distant village. He wanted the record to be as complete as possible.

And what a record! The Schuster archive holds, in addition to the 18,000 pages of detailed correspondence, some 275,000 annotated photographs, more than 70,000 negatives, 5,670 bibliographic references, and more, all cross-referenced five ways, with a master catalog in thirty languages (including five alphabets).

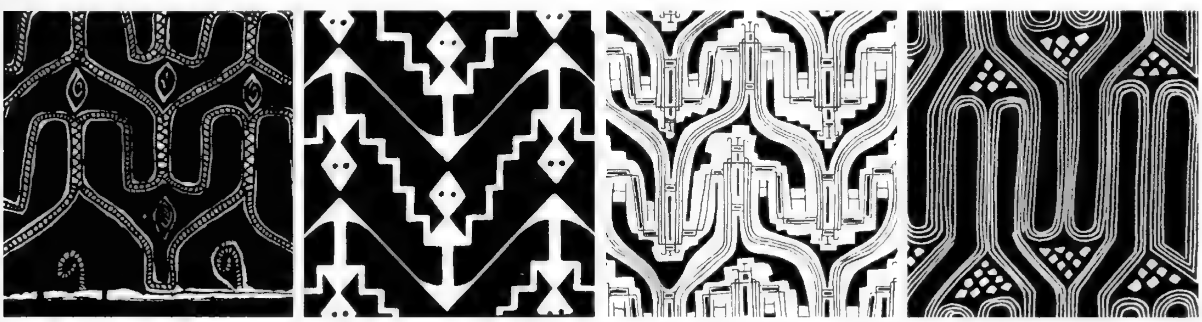
If forty scholars with forty grants had labored forty years, they couldn't have produced an equal archive. Yet Schuster worked alone. His ceaseless travels, all miracles of frugality, took him wherever the evidence dictated, including villages reached only by camel or dugout canoe. An open, easy manner brought acceptance.

When I promised him I would complete his work, I reckoned the task would take a year. Eighteen years later I published *Social Symbolism in Ancient & Tribal Art,* a twelve-volume compendium of Schuster's findings, 3,500 pages with 7,000 illustrations. Sets were deposited in 600 libraries around the world. Subsequently I published a more digestible one-volume summary, *Patterns That Connect* (1996). Rodney Needham, a noted professor emeritus of social anthropology at the University of Oxford, expressed his admiration for the latter volume:

> Just to scan the illustrations and assess them in relation to their times and places is very exciting. Merely their juxtaposition poses such profound questions that it is hard to understand an anthropology that does not confront them.

"I find myself lamenting the fact that Schuster is no longer alive," wrote the art historian Leo Steinberg of the University of Pennsylvania. "A strange sentiment," Steinberg went on, "for I never mind learning that Einstein is dead or Humboldt or Paracelsus. But with this man there is so much I would like to discuss."

Even more than this one man, though, the elegance of genealogical iconography evokes admiration. That shouldn't cause surprise. People everywhere are pattern-makers and pattern-perceivers. Our Paleolithic ancestors shared that gift. Thanks to Carl Schuster, we descendants can celebrate their achievement. □



Designs copied from artifacts collected in various parts of the world bear a striking resemblance to one another (left to right): New Guinea bamboo pipe, nineteenth century; Iranian pottery, ca. 3000 B.C.; pre-Columbian Brazilian pottery, A.D. 400–1300; Congolese wooden cup, nineteenth century. Because human figures are such a central subject of tribal art, these designs may have been independently invented. But the author hypothesizes that they have embodied the important social concept of genealogical connection since Late Paleolithic times and have continued to convey that concept within traditional tribal groups.

Female aplomado falcon (above), raised as part of a captive-breeding program, takes wing in southern Texas, not far from where she was released into the wild a year earlier. Aplomados often hunt in mating pairs, such as the couple shown on opposite page chasing down a sparrow.

Home above the Range

Pairs of aplomado falcons are nesting in the Southwest again, showing off their incredible hunting and flying skills.

By W. Grainger Hunt, Tom J. Cade, and Angel B. Montoya

A small flock of red-winged blackbirds is flying fast, with the wind, when a larger bird launches upward and picks out a target from the moving group. Bird chases bird, one hunter, one prey. In level flight the hunter turns on a burst of speed—firing up its afterburners, so to speak—and closes the gap on the prey. The blackbird looks like a goner, as if somehow the wind had shifted against it or some unseen force were pulling the smaller bird toward its antagonist. Just in time, the blackbird takes evasive action, by jinking and diving for cover.

But the hunter has an unusually long tail, a strong rudder that gives it agility as well as speed. Another pursuer might respond to the blackbird's darts and evasions with a wide, banking turn before returning to the chase; instead, this hunter abruptly reverses direction and follows closely as the blackbird makes a mad, twisting, zigzag dash for a bush. Not a second too soon, the prey dives into the bush, while the hunter shoots past and climbs steeply, looking down over its shoulder at the missed prize.

Many hunting birds, including the peregrine falcon and others, give up if their intended prey reaches cover. Incredibly, though, this hunter seems to be in two places at once. As it rises and circles, a second hunter—its wingman, so to speak—plunges into the bush and flushes out the hiding blackbird. The flying chase begins anew.

In fact, there are two hunters: a breeding pair of falcons known as aplomados (*Falco femoralis*) that work together, anticipating each other's next move. Observing a single aplomado or a cooperative hunting pair in flight is a wondrous experience. The lofty bird-on-bird chases feature thrilling, split-second escapes, astonishing aerial acrobatics, and often, in the end, a successful kill. Like the gyrfalcon and the merlin, the aplomado can suddenly accelerate in level flight. And, if the prey tries to escape by flying upward, the aplomado can follow it, climbing at a steeper angle than even the gyrfalcon. Again and again it may climb above its prey, harassing it with repeated raking passes. And unlike the far-ranging flights of the gyrfalcon or the peregrine, the aplomado's proclivity for tight turns often keeps the entire sequence within sight of the human observer [*see illustration on pages 52 and 53*].

Not many people have heard of the aplomado falcon, let alone seen it in action. Its slow-blooming reputation has long been eclipsed by such legendary bird hunters as the gyrfalcon, the merlin, and the peregrine. As falcons go, the aplomado is about average in size, weighing in at just under a pound: smaller than both the peregrine and the gyrfalcon, and larger than the merlin. Compared to those birds, the aplomado's most unusual characteristic is its long tail. But it is no peacock plume. The tail is reminiscent of the tails of the largely insectivorous kestrels and hobbies or, to cite other hunting birds, of the tails of accipiters—hawks known for their sharp turns—such as the Cooper's hawk. And even the name *aplomado*, a Spanish word meaning "lead-colored," distinguishes only

Adult aplomado perches next to a raven's nest that it has commandeered on an abandoned windmill, in the Mexican state of Chihuahua. Falcons do not build their own nests.

the bird's gray back, and ignores the beautiful cinnamon-orange markings on its head and belly.

Early naturalists did admire the aplomado's colorful markings and yellow-rimmed eyes. Yet, these "admirers" hardly countered the bird's relative anonymity by also describing it as rather phlegmatic and an unexciting predator. According to their descriptions, the aplomado would perch quietly for long periods in trees or on fence posts; or, it would follow grass fires to catch escaping grasshoppers and other small prey flushed out ahead of the conflagration. Had any of them seen the bird in hunting mode?

Only the ornithologist and artist Andrew Jackson Grayson, traveling in Mexico in the 1860s, seems to have observed aplomado falcons closely enough to fathom their true nature. He watched them chase doves and other medium-size birds—and came away impressed by their spectacular flying and hunting tactics. He thought them not unlike the sharp-shinned hawk, another accipiter. Grayson was right; the assumption that the aplomado is an unremarkable hunter is as far from the truth as a newborn tundra peregrine is from its future wintering grounds in Argentina.

No records indicate that French or Spanish falconers of the sixteenth and seventeenth centuries knew of a bird by the name aplomado. But they did train a small falcon, known to the French as *alethe* and to the Spanish as *aletto*, that came from the New World. Early conquistadors and explorers had encountered the bird in Mexico and Central and South America, recognized its abilities, and brought it back to European falconry centers in France, Spain, and Portugal. In a famous popular treatise, *La Fauconnerie*, first published in 1598, the aristocrat Charles d'Arcussia wrote of hunting gray partridges with the New World falcon. He favorably compared the alethe to the gyrfalcon and goshawk, for its direct flights from the falconer's glove. D'Arcussia also referred to the bird as "high-mettled" and full of spirit.

In 1995 James W. Nelson, a falconer from Kennewick, Washington, studied those historical descriptions of behavior and appearance. He had, at that point, also carefully studied the hunting behavior of wild aplomados. The alethe, the aletto, and the aplomado, he declared, were one and the same.

Back in 1976, a young graduate student in biology, Dean P. Keddy-Hector, then at Oklahoma State University in Stillwater, made the first attempt to scientifically study the behavior and ecology of the aplomado species. He drove down the coast of eastern Mexico to look for them, not being certain that there were any falcons left to study. At the time, Mexican farmers were still dusting their crops with the chemical pesticide DDT—the bane of falcon reproduction because it thins their eggshells. By then, the destruction of the aplomados' natural habi-

tat had already driven them from the United States, though the birds had lived in the southwest until the early 1900s [*see map on this page*]. Early naturalists had spotted them fairly often in parts of southern and western Texas, southwestern New Mexico, and southeastern Arizona. But heavy livestock grazing and fewer natural fires had turned grasslands into scrublands. Wet savannas, moreover, had been converted to cropland. The last sighting of aplomado nesting pairs in the U.S. was in the 1950s.

But Keddy-Hector did find aplomados in Mexico. They stood out brightly against the blue sky in the coastal state of Veracruz, perched above the rich grasslands in the tops of lone acacia trees. They laid their eggs in the abandoned nests of other large birds and in bromeliads, or air plants [*see photograph on opposite page*]. And, like all tropical falcons, they ate insects.

Keddy-Hector showed, however, that insects make up only a small part of the aplomado diet—appetizers, you might say, though still important to young, inexperienced falcons learning to hunt. The staff of life for aplomados proved to be other birds: a myriad of resident and migratory species passing through the falcon territories. The aplomados could catch these prey from standing starts in treetop perches. And, once in the air, they could easily close a quarter-mile gap in pursuit of, say, a passing flock of doves.

Current and historically known ranges of aplomados in the U.S. and Mexico are plotted above. Colored question marks indicate historical ranges that are not well documented. The small areas in Texas marked as current ranges are regions where aplomados have been reintroduced. The species also occurs in Central and South America.

Hunting is not the only chance for aplomados to show off their talent for stupendous flying. They are fiercely territorial and seek to drive away any large bird that enters their turf. Highest on their list of undesirables are other aplomados; nests are therefore widely spaced across the landscape, usually miles apart. Other species singled out for special disdain are hawks, owls, and ravens—and for good reason. The low trees of the savanna offer little protection from such predators for aplomado nestlings. The best strategy for parent aplomados, then, is to attack on sight, giving the territory itself a hostile reputation. Whenever they attack, the aplomados also steal any prey the intruders may be carrying, giving them yet another reason to stay away.

By the late 1970s, the loss of breeding aplomados in the U.S. had stirred enough regret among conservationists that they began taking action. Eggshell thinning caused by DDT in eastern Mexico was also detected by Keddy-Hector, attracting more attention. People began wondering whether the aplomado in Mexico might be going the way the peregrine had two decades earlier: total loss of breeding pairs in the eastern U.S. The Peregrine Fund, an organization founded in 1970 by one of us (Cade), was already restoring peregrines to their native habitat by releasing captive-bred young. So it was a small step to suggest that aplomados might benefit from similar intervention.

With the cooperation of the Mexican government, John Langford, a biologist at the Chihuahuan Desert Research Institute in Alpine, Texas, and his coworkers brought eight young aplomados from Mexico back to Texas. There, in 1982, the first captive-born hatchling emerged. In 1990 more birds from Mexico were bred, in order to enrich the genetics of the original seed population. After fits and starts with artificial insemination, rearing methods, and pilot releases, more than fifty young aplomados were being raised and seemed ready for release. Conservationists were finally in a position to make the first large-scale attempt at restoring the species to nature. But where?

The savannas of coastal southern Texas seemed to offer the best chance for re-establishment. The region had included vast savannas at the time of the Spanish settlement in the 1600s. Brush invaded, though, and by the early 1900s, most of southern Texas was either developed as farmland or blanketed in brush. But even with such large-scale loss of habitat, aplomados bred just north of Brownsville, Texas, until the mid-1940s. The final loss of the species in southern Texas coincided with the arrival of DDT in 1947 for cot-

ton production. With DDT in their diets, aplomados had little chance of reproducing.

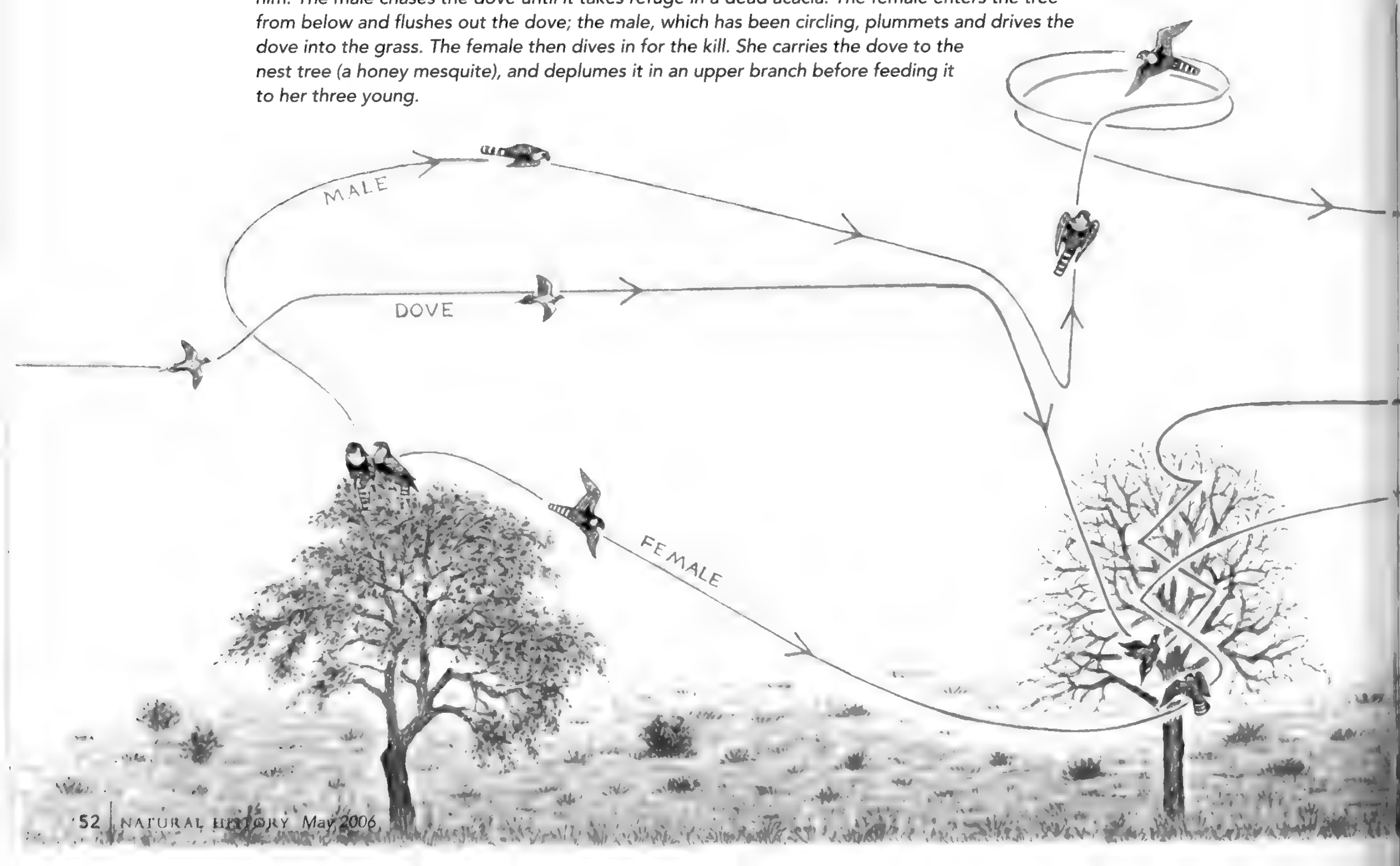
By the early 1990s, though, DDT contamination was in decline, and many species that had been harmed by the pesticide were rapidly recovering in other parts of the U.S. So J. Peter Jenny, Brian D. Mutch, and William R. Heinrich, all biologists with the Peregrine Fund, began looking for pockets of open savanna on the big ranches and wildlife preserves of southern Texas. Most promising were tracts near the Gulf Coast, particularly where grasslands were being improved through controlled burning and other methods of brush removal.

Captive aplomados were first released on a substantial scale in 1993, via a technique invented by European falconers called hacking. Groups of fledgling aplomados were placed in protective, ventilated boxes on the tops of wooden towers. Attendants covertly placed food in the boxes, then, after a few weeks, opened the boxes so the birds could fledge on their own. Soon the young aplomados were exploring their environs and returning to the tower for food.

As they did so, however, a potent predator emerged: the great horned owl, a species that had benefited from the centuries-long invasion of thorny brush. New release areas had to be carefully screened for owls—ideally, as far from brushy areas as possible. Maturing aplomados posed another, unexpected threat to the newly released young. Once the older falcons learned to be self-sufficient, they dispersed into the landscape, only to return the following year to defend territories close to the hacking towers. There they became aggressive toward the young falcons being released. Workers thus had to prospect constantly for new release sites.

In May 1995, the first wild, productive breeding pair was discovered in southern Texas; since then at least two centers of breeding have emerged. Twenty-six breeding pairs now nest in the vicinity of the Laguna Atascosa Wildlife Refuge near Brownsville, and thirteen more pairs nest on Matagorda Island north of Corpus Christi [*see map on preceding page*]. Both areas make ideal habitats for foraging aplomados—the landscapes are vast, open, replete with birdlife, and moderately free of owls. Biologists are cautiously optimistic about the growing aplomado

Cooperative hunting sequence, similar to one observed in the central Mexican state of San Luis Potosí, is depicted as it unfolds, from left to right, in the schematic diagram. A male aplomado—perched with his mate in an acacia tree—tries to intercept a passing dove, but the dove evades him. The male chases the dove until it takes refuge in a dead acacia. The female enters the tree from below and flushes out the dove; the male, which has been circling, plummets and drives the dove into the grass. The female then dives in for the kill. She carries the dove to the nest tree (a honey mesquite), and deplumes it in an upper branch before feeding it to her three young.



population. And as visitors to Laguna Atascosa know, southern Texas has become a place to watch aplomados in action.

In the 1970s and 1980s, people had come to think that regions farther west, such as the desert grasslands of Texas, New Mexico, and Arizona, were devoid of nesting aplomados. But rare sightings of lone falcons suggested the possibility of a population in nearby Mexico. One of us (Montoya) became so curious that, in 1992, he and two other biologists—Robert Tafanelli, then at New Mexico State University in Las Cruces, and Manuel Bujanda, now at the University of Chihuahua, Mexico—began exploring the back roads of the Mexican state of Chihuahua. One day, as they were traveling through an immense grassland with a scattering of tall yuccas, they happened upon a pair of aplomados perched on adjoining fence posts, preening nonchalantly in the sunshine. During the next few years, Montoya, Tafanelli, and Bujunda discovered nearly forty pairs scattered among the cattle ranches of the region.

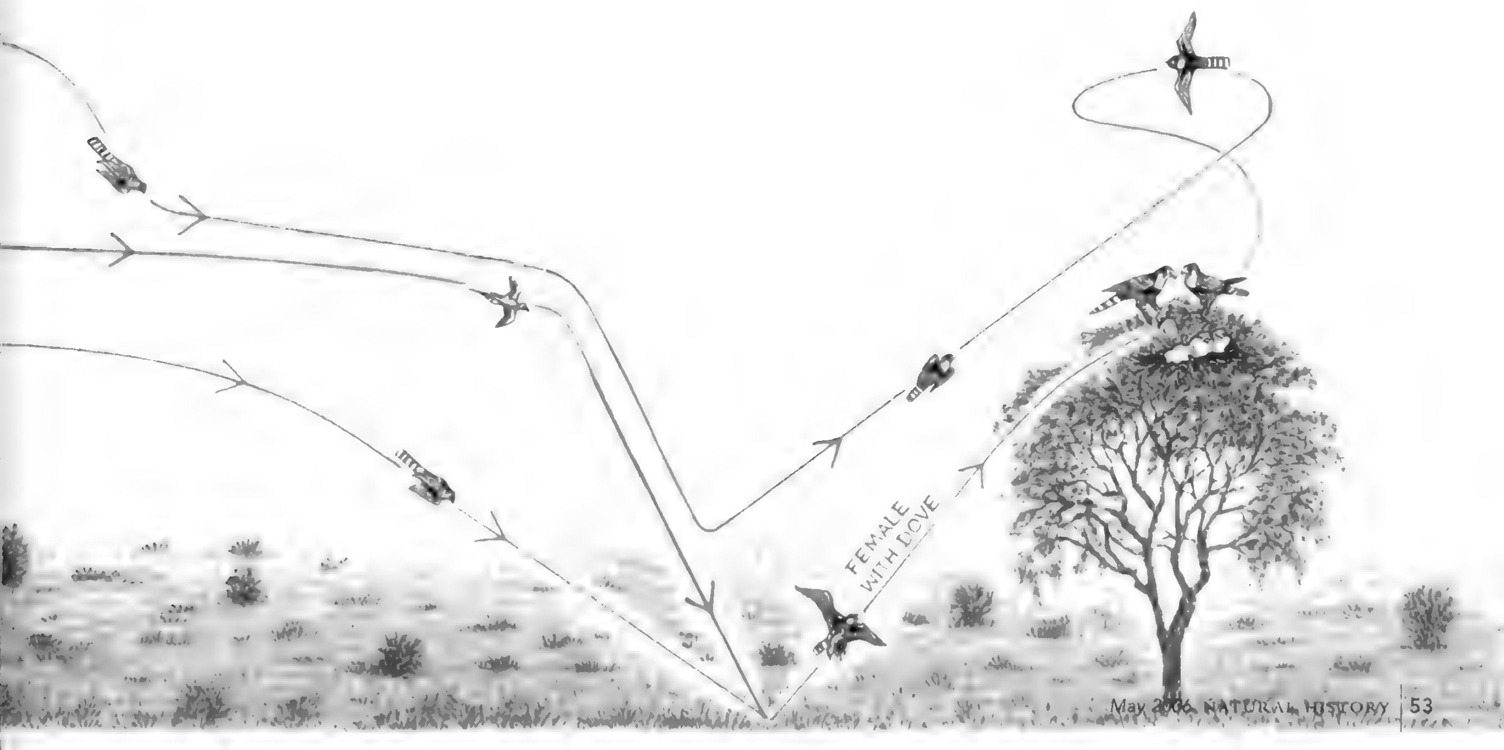
Why did aplomados persist in Chihuahua, when they had vanished from the U.S., only a few hundred miles away? The answer has largely to do with the history of ranching. In the U.S., by the 1870s, the railroad had connected the grasslands of southern New Mexico with the markets of the East, altering the economics of cattle production. A sea of fertile grasses, once largely inaccessible to livestock, was opened up as trains carried equipment for drilling wells and building windmills, earthen dams, and watering tanks. The supply of grassland seemed limitless, and entrepreneurs showed little interest in long-term sustainability. But the cattle caused massive erosion. Woody plants such as creosote bush and mesquite moved in, smothering the open grasslands.

Desert savannas in Mexico were affected far less extensively than their counterparts in the U.S., in part because the development of man-made water sources for livestock in Mexico was so long delayed. Groups of hostile Apaches on the Mexican side of the border in the late 1800s also made remote ranching risky and unprofitable. The Mexican Revolution of 1910 further retarded the development of the region.

The persistence of suitable habitat for nesting aplomados in Chihuahua also owes much to the long-established ranching families who managed their lands with care through long cycles of wetness and drought. Enrique Baeza, the owner of a 100,000-acre ranch called the Tinaja Verde, in eastern Chihuahua, belongs to such a family, and he knows the aplomado well. To him, nesting aplomados show how well he is caring for his ranch:

> My dad wanted to pass this ranch on to his kids, and that's what I want to do for mine. The advice Dad gave me was to graze as if [drought conditions] next year will be worse than this one. That's what we do. We graze year round, but we graze lightly—it's a tradition with us. Aplomados are a thermometer for what we're doing.

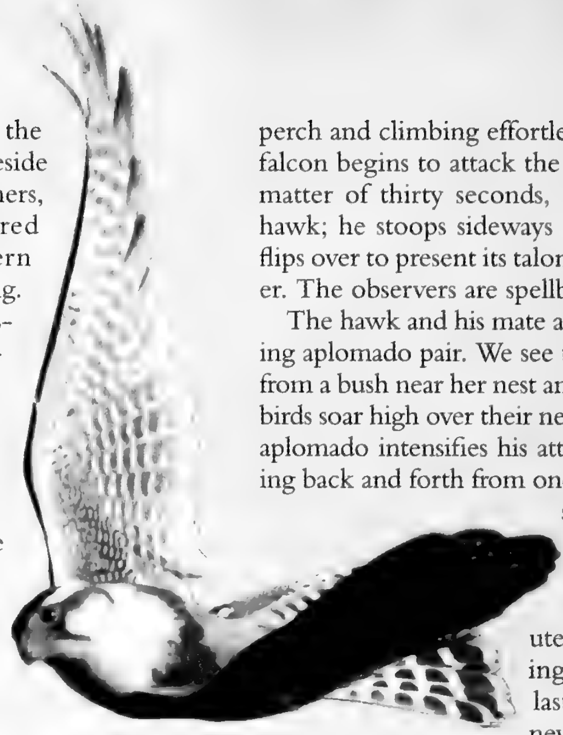
The thirteen pairs of aplomados nesting at Tinaja Verde are indeed good indicators of the health of the grasslands. They occupy a key node in a food web that includes grasses, seeds, insects, and small



birds. Some of the species in the web, such as the meadowlark, reside in the grasslands year-round; others, such as the chestnut-collared longspur, arrive from northern prairies in fall and depart in spring. Both are important, but the presence of wintering birds is crucial, particularly at the beginning of the aplomado nesting season. That's when the falcons are storing fat to produce and incubate their eggs. Thus, the aplomado also depends on the habitats that nurture the migrants—some from as far away as Alberta, Canada.

Alberto Macías-Duarte, now at the University of Arizona in Tucson, studied the migrants and other factors affecting aplomado ecology at Tinaja Verde and at the neighboring Coyamito Ranch. He examined the impact of bird abundance on falcon breeding success, and showed how both were affected by the severe drought that has gripped the region since 1993. The drought, he suggests, has led to such severe declines in the abundance of prey birds that the falcons must travel extra distances from their nests to forage. That demands more energy, and exposes the young falcons to increased predation by ravens and others.

Releases of aplomados on two cattle ranches in west Texas began in 2002, but they are still in the early stages. Unlike southern Texas, where food is abundant and predation is the central issue, food may be the biggest challenge for aplomados in the desert grasslands. Time will tell whether west Texas, with its vast open lands and vegetation so similar to that of neighboring Chihuahua, will have enough doves, meadowlarks, and other medium-size birds to support a breeding population of aplomado falcons.



Aplomado banks into a dive.

In the tall weeds of a derelict landing strip on the far end of Matagorda Island, Texas, two of us (Hunt and Cade) have joined Erin J. Gott and Paul W. Juergens, both biologists for the Peregrine Fund. Gott and Juergens are taking turns peering through a telescope, attempting to identify the band numbers of a pair of aplomados perched on a low shrub. The falcons are trying to decide whether to accept the new nesting platform provided for them, or to lay their eggs in an abandoned nest in a nearby bush. The male glances up and spies a white-tailed hawk casually soaring 400 feet above. Flashing off his low perch and climbing effortlessly at a steep angle, the falcon begins to attack the much larger hawk. In a matter of thirty seconds, the falcon is above the hawk; he stoops sideways and down, as the hawk flips over to present its talons. The hawk soars higher. The observers are spellbound.

The hawk and his mate are neighbors of the nesting aplomado pair. We see the female hawk take off from a bush near her nest and join her mate; the two birds soar high over their nesting territory. The male aplomado intensifies his attack on both hawks, flying back and forth from one to the other, executing shallow, slashing stoops over their backs, sometimes actually hitting them. After several minutes our group begins timing the encounter, which lasts about forty minutes; never once does the little falcon stop attacking or set his wings in a glide or soar. Running at fifteen to twenty times his resting metabolic rate, he is consuming a huge amount of energy in the continual, rapid beat of his wings. Nothing is more important for survival and reproduction than defending his nest and food supply, and his behavior shows it. According to Juergens, the falcon and hawk pairs fought relentlessly during last year's breeding season, but both still managed to raise their young.

In spite of such tenacity, aplomados have disappeared from much of their former range. That is one reason the U.S. Fish and Wildlife Service listed them as an endangered species in 1986, even though the population in coastal eastern Mexico is extensive. There is little immediate hope for an aplomado comeback in much of the drier ancestral region to the north, because of the large-scale brush invasion. But, as Enrique Baeza has learned, what is good for aplomados is good for cattle ranching. Biologists are pinning their hopes for the species on that fact. The presence of this beautiful falcon is a sign of prosperity, of landscape richness; its reappearance is a sign that things are going well.

If the aplomado makes a full recovery over the long term, breeding aplomados will spread across the Chihuahuan Desert grasslands of northern Mexico and the southwestern U.S. For an increasing number of us, the sight of two adult aplomados perched together on the spike of a tall yucca, looking out across a sea of yellow grasses for the movement of an oriole or longspur, or racing together toward a soaring, absent-minded redtail, is a reminder of how much our lives and livelihoods are nourished by such natural processes. □

Short Horse Mountain, part of Massanutten Mountain, looking south from Storybook Trail

Virginia Is for Hikers

Massanutten Mountain has forest trails, streams, shale barrens, a muskeg, and spectacular views.

By Robert H. Mohlenbrock

The Appalachian Mountains, which extend 1,600 miles from Quebec's Gaspé Peninsula to the coastal plain of Alabama, embrace several ranges that roughly parallel the Atlantic coast of North America. In Virginia three main swaths of mountains are distinguished: the Allegheny Mountains in the west, the Blue Ridge Mountains to their east, and a combination of mountains and major river valleys in between.

One of the "in between" mountains is Massanutten, comprising two parallel ridges that extend fifty miles, from near Harrisonburg in the southwest to near Strasburg in the northeast. Rising to nearly 3,000 feet, the mountain is heavily forested: dry forest covers the crests, and moist forest is found in the riparian, or streamside, zones. Most of Massanutten Mountain lies within George Washington National Forest, which maintains forest roads and trails. A visitor center along U.S. Highway 211, where it crosses the mountain east of New Market, is open from mid-April through October.

Mountain laurel blooms on Massanutten Mountain in early May.

Massanutten Mountain is formed from layers of sedimentary rock—shale, sandstone, limestone, and more shale—that was deposited by shallow coastal seas. When the Appalachian Mountains arose, between 480 million and 300 million years ago, those layers were folded into a U-shape, creating the two parallel ridges visible today. The Storybook Trail, a short hiking trail off Forest Development Road 274 (Crisman Hollow Road), about two miles north of the visitor center, offers several displays depicting the mountain geology. The trail ends at a spectacular overlook.

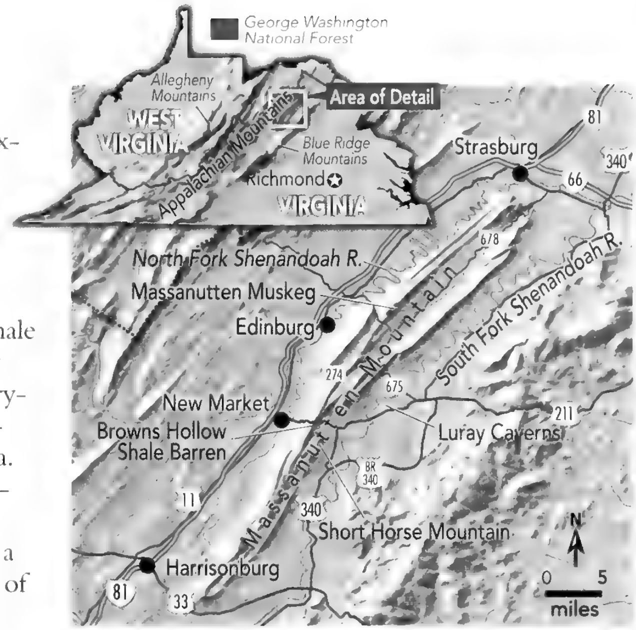
Among the trails that originate at the visitor center are Discovery Way and Wildflower Trail, both short, and Bird Knob Loop Trail and Waterfall Mountain Loop Trail, each more than eight miles long. For the ambitious backpacker, the seventy-one-mile-long Massanutten National Recreation Trail is accessible from many points along its way. The trail

is a loop that follows one ridge and backtracks along the other.

Near the midpoint of the mountain, east of Edinburg, my wife Beverly and I explored the Peters Mill Run Trail. (That trail, it's worth cautioning, is open to all-terrain and off-highway vehicles.) Along it we came to a boggy area kept wet by seepage from the adjacent hillside. We were careful to observe it from the periphery, both because some plants rare for the region grow there, and because the black muck would have made for hard walking. In one place the boggy soil is four feet deep, and it trembles if you walk on it. Such boggy areas, more common far to the north of Virginia, are called muskegs, from a Native American word that means "grassy bog." Virginia botanists are quite familiar with this one, locally known as the Massanutten Muskeg. It harbors several northern plant species that here reach their southern limits.

At the other extreme from that soggy habitat are shale barrens, dry, exposed places where crumbling rock, searing summer temperatures, and acidic soils limit growth to a few well-adapted species. Shale barrens are known only from a few areas in Maryland, Pennsylvania, Virginia, and West Virginia. One is the Browns Hollow Shale Barren, on Massanutten Mountain a few hundred feet south of the visitor center. Steep south- and east-facing shale slopes rise as high as 120 feet above Browns Run, a stream that flows through the hollow.

ROBERT H. MOHLENBROCK is a distinguished professor emeritus of plant biology at Southern Illinois University Carbondale.



VISITOR INFORMATION
Lee Ranger District
George Washington and Jefferson National Forests
109 Molineu Road
Edinburg, VA 22824
540-984-4101
www.fs.fed.us/r8/gwj/lee/

Habitats

Dry forest Common trees include black gum, black oak, blackjack oak, black walnut, eastern red cedar, northern red oak, pignut hickory, rock chestnut oak, slippery elm, sassafras, Virginia pine, white ash, white oak, white pine, and wild black cherry. Among the smaller trees and shrubs are black haw, black raspberry, common blackberry, deerberry, hillside blueberry, and mountain laurel. Wildflowers often present are common blue heart-leaved aster, goat's rue, hemp dogbane, oxeye daisy, trailing arbutus, wrinkle-leaved goldenrod, and yellow wild indigo.

Riparian forest Mountain maple, sugar maple, sweet birch, and yellow poplar (also called tulip tree) are the dominant trees, rising above a middle forest layer of downy serviceberry and redbud and a ground layer of bland sweet cicely, mayapple, pink lady's slipper, large twayblade, white avens, and wild geranium. The wettest areas support box elder, northern hackberry, red maple, and shellbark hickory, along with the shrubby spicebush and such wildflowers as American water-willow, clearweed, dwarf crested iris, fringed loosestrife, southern three-lobed bedstraw, and Virginia dayflower.

Muskeg Black ash, unusual for the mountains of Virginia, grows with red maple, sweet birch, and yellow poplar. Shrubs include such wetland species as arrowwood, ninebark, spicebush, and winterberry, as well as species that prefer drier habitats, such as American hazelnut, fringe tree, pawpaw, and witch hazel. Bog-loving orchids thrive in the muskeg. Among them are club-spur orchid, grass-pink, Loesel's twayblade, purple fringed orchid, ragged fringed orchid, showy lady's slipper, and yellow fringed orchid. Species uncommon this far south are American golden saxifrage, marsh marigold, meadow phlox, round-leaved sundew, swamp lousewort, and tawny cotton grass. Cinnamon fern, lady fern, marsh fern, royal fern, and shining club moss are among the spore-producing plants in the bog.

Shale barrens A sparse woodland of eastern red cedar and Virginia pine grows above the herbaceous plants. Some of the latter are common, such as little bluestem and Pennsylvania sedge. Others are endemic to shale barrens, such as shale barren goldenrod, shale barren rock-cress, Virginia whitehair leather flower, and white-hair leather flower.

By Laurence A. Marschall

Field Notes from a Catastrophe: Man, Nature, and Climate Change
by Elizabeth Kolbert
Bloomsbury Publishing, 2006; $22.95

From a scientific standpoint, one might argue, we don't need another book on global warming. Everyone, it seems, knows about melting icecaps and hyperactive hurricanes. If you ski, you curse the warmer winters. If you own beachfront property—or reside on a coral atoll—you fear rising sea levels.

What is more, scientists seem to be in general agreement about the parameters of the scientific problem, even if some details of the current thaw remain to be determined. Few scientists doubt that the Earth's mean temperature has been rising at a rate unprecedented in recent geological history. Few question the increased concentration of greenhouse gases in the atmosphere, and few deny that the burning of fossil fuels is the major source of this increase. And though computerized models lead to divergent predictions about which factors ultimately have the most effect on future climate, there is little disagreement that some kind of climatic change is in progress. Dramatic changes have taken place in the past, and there is no reason to expect today to be any different. Scientifically speaking, global warming is old news.

But because of the nature of global warming—transnational in scope, and very likely tied to pollution caused by human activity—what to do with the bare facts is a political problem. From that point of view, Elizabeth Kolbert's book is more than welcome. Politicians, as you may have noted (more and more these days), are relatively insensitive to the raw power of scientific arguments. Faced with proof that the sky is indeed falling, decision makers still need to feel the will of their constituents: voters who would prefer that the sky not fall, and who make it clear that public and private funds should be devoted to keeping the sky from falling.

Elizabeth Kolbert presents a series of succinct and astutely written bulletins from the front lines of the climate-change community, and her assembly of the "old news" may still change the right minds in the right places. Rather than reviewing the usual evidence, she has sought out voices who speak with knowledge and conviction about what is happening to the planet. The most dramatic effects of global warming, she notes, occur in places where the fewest people live, so she journeys to a small island in the Arctic Ocean, barely ten feet above sea level. Vladimir E. Romanovsky, a Russian geophysicist who has been watching the island crumble in the past decade as its permafrost melts, gestures at the eroding bluffs. "Another disappearing island," he says. Climate change is "moving very, very fast."

Erosion on Sarichef Island, Alaska, from storms and rising sea levels has forced the inhabitants to abandon the island for the mainland.

It's moving just as fast on Greenland's vanishing ice sheet, where the Jakobshavn Isbræ, a moving river of ice, has more than doubled the rate of its slide to the sea, from 3.5 miles per year in 1992 to 7.8 miles per year in 2003. And it's moving fast in Iceland, too, where Kolbert views the Sólheimajökull, a glacier that has retreated a fifth of a mile in the past decade. By the end of the century, an Icelandic glaciologist tells her, the island, which has been continually glaciated for at least 2 million years, will be virtually ice-free.

What climatologists worry about most, Kolbert writes, is that humanity may reach a tipping point, the state of "DAI," or Dangerous Anthropogenic Interference, where calamitous change becomes inevitable. Climate modelers such as James E. Hansen of NASA's Goddard Institute for Space Studies, whom Kolbert visits in New York City, are hesitant to predict when the Earth will cross the DAI line, or whether we have crossed it already. But Hansen—who recently made headlines when he complained of being muzzled by political appointees in his agency—and many of the other scientists, agency functionaries, and political veterans interviewed by Kolbert express dismay that what seems to be the policy in the face of the gathering storm is "business as usual."

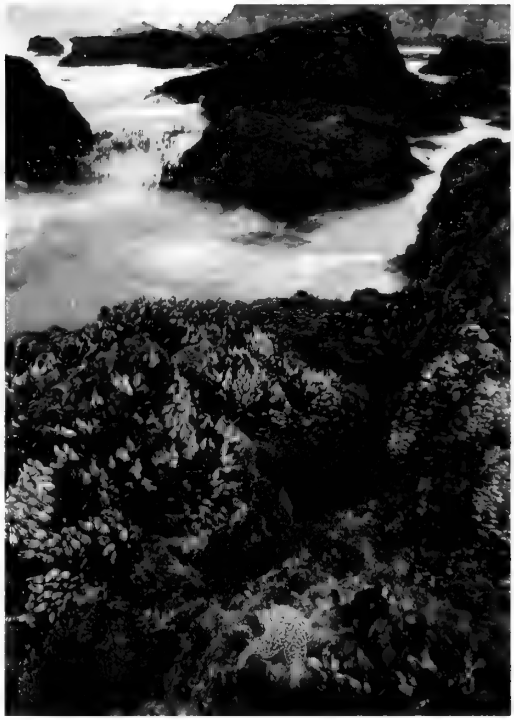
It's hard not to share their concerns, especially when Kolbert conveys their insights with such immediacy and cogency. Take, for instance, the comment made by another NASA scientist, sipping coffee in a tent atop Greenland's melting ice sheet: "To put it nicely, we are heading into deep doo-doo."

Wave-Swept Shore: The Rigors of Life on a Rocky Coast
by Mimi Koehl; photographs by Anne Wertheim Rosenfeld
University of California Press 2006; $39.95

Successful symbiosis—the kind that makes green algae and sea anemones flourish in the intertidal zones along seacoasts—takes place between organisms whose disparate talents complement each other to the benefit of both. The anemones, whose short, barrel-shaped bodies are firmly anchored to rocks, pro-

vide a sheltered habitat for the algae, which might otherwise be swept away by the waves. When tides are high, the anemones unfurl their crowns of tentacles into the sea, snagging mussels that float by. At the same time, photosynthetic algae in their guts, exposed to sunlight, provide added nourishment to both themselves and their anemone hosts. Algae and anemones form a partnership that works.

So, too, do Mimi Koehl and Anne Wertheim Rosenfeld. Koehl, a Berkeley professor, is an expert in biomechanics. She has made her mark in studying how the structures of organisms help them function in particular environments. Why, for instance, aren't starfish peeled from rocks by the surf? (The answer: hard grit embedded in exposed areas of soft tissues makes them stiff enough to resist breakage; underneath, hundreds of tubelike feet hold the starfish in place.) Rosenfeld, by contrast, is a veteran nature photographer; eighty-seven of her exquisite pictures of the creatures and micro-inhabitants along a short stretch of California coast provide an eye-catching and instructive accompaniment to Koehl's descriptive prose.



Eddies that form between rocks as tides ebb and flow stir up the water and draw away wastes from the animals and plants that live on the shore.

Wave-Swept Shore is a field guide not to the creatures that inhabit the intertidal zone, but to the processes that enable them to live together in such a challenging habitat. In a few short chapters Koehl shows how their design helps them deal with the challenge of an environment that is alternately dry and wet, scoured by surging currents and dessicating winds. How do plants and animals anchor themselves? How do they protect their bodies against the relentless stress of flowing water? How do they find food, eliminate wastes, and reproduce?

Leafing through the book, it's clear that nature has devised a variety of solutions to these problems. Some littoral creatures—barnacles, for instance—secrete a remarkable glue that bonds them so firmly, even to wet surfaces, that they can weather the fiercest storm. When they get amorous, though, they are, literally, stuck. Unlike crabs, which can scuttle long distances in search of a mate, barnacles can only marry, as it were, the girl next-door. To this end, each one (barnacles are hermaphrodites) has a penis long enough to reach other nearby barnacles. "If you bolt a camera to the rocks to record what barnacles do when the tide is in," writes Koehl, you'll see that, when they are not filtering food from the water, they are "snuffling around the neighborhood with their penises, perhaps checking out potential mates."

For barnacles and most other creatures of the intertidal zone, the constant waves are both a curse and a blessing. Many adaptations are, in essence, protective measures against the flow of water—protective shells, streamlined shapes, suckers that cling and adhesives that stick. But tidal creatures also depend on moving water to bring in the microplankton they eat, to scatter eggs and distribute larvae, and to dilute and flush away wastes. "Try to feel the environment met by the animals and plants clinging to these rocks," Koehl advises. Together she and Rosenfeld ably do just that, conveying the feeling that—for sea squirts, mussels, and goose barnacles at least—the rocky coast is the best of all possible worlds.

Fish on Friday: Feasting, Fasting and the Discovery of the New World
by Brian Fagan
Basic Books, 2006; $26.95

Fish have been a culinary delicacy in most cultures, yet oddly, in most of medieval Europe, they were regarded as something of an acquired taste. For centuries, the Catholic Church judged that eating fish was a form of self-denial, and permitted its consumption on fast days when other, more desirable foods were banned. The days of fasting and penance included the forty days of Lent, as well as Fridays and miscellaneous holy days. As the Church came to dominate European society, an enormous demand for fish developed that, eventually, local resources could not supply.

Brian Fagan, emeritus professor of anthropology at the University of California, Santa Barbara, weaves these themes together into a fascinating history of the fishing industry in Europe, from Roman times until the colonization of North America in the 1600s. It would be an overstatement to argue that the New World was settled because Catholics needed fish to obey ecclesiastical strictures. But Fagan makes an excellent case that the lure of rich fishing grounds should be given equal weight, with the quest for gold and spices, as forces that drove Europe's westward expansion.

Until the eleventh or twelfth century, according to Fagan, most fishing was done locally. Eels were among the most abundant species, and were so prized that in some markets they were used as a form of currency (one can only imagine how modern vending machines would work if the practice had continued). Herring were also abundant, but

harder to preserve, even if heavily salted. Coastal villagers may have relished them, but away from the coast they were viewed with distaste, food fit only for the poor. Pond-raised carp were also devoured by the devout, but it was not cheap to raise them, and their muddy flavor was not to everyone's taste.

Cod, however, had become the staple fish of European Catholics by the dawn of the great voyages of discovery. First fished by the Norse, it is a flaky white flesh that is nutritious and palatable even to finicky eaters. More important, cod was readily air-dried in northern climates, to produce plank-like filets called stockfish that would keep as long as five years. Stockfish could also be turned back into white flesh with a few minutes of pounding and a good soaking in water. It satisfied the appetites of a growing population of Catholics, and served as a form of K rations for armies and navies throughout the continent.

Some of the history of cod has already been told by Mark Kurlansky in his 1997 bestseller, *Cod.* But despite their superficial similarity (both books are punctuated by fish recipes that made this reader head for the kitchen), Fagan's book is heavily annotated and the more scholarly of the two. It also differs with Kurlansky on the question—always contentious—of who discovered the rich cod-fishing grounds off Newfoundland and New England. Kurlansky thinks it was the Basques, who kept their knowledge secret for centuries. Fagan makes a convincing case for the merchants of Bristol, in Western England, who financed ships bound for the New World in increasing numbers in the 1500s. The first settlements in New England were fishing stations, not colonies of Pilgrims, and the fish trade ultimately brought England more profit than trade in any other commodity from the New World.

Giovanni Antonio Bazzi (known as Il Sodoma), Story of Saint Benedict *(detail), sixteenth century*

Whether Fagan overstresses the role of fish and ships on the European voyages of discovery, his book is a reminder of how important movements in history can be shaped by forces of everyday commerce, which are often overshadowed by the glitzier themes of conquest and riches. Put this book on your reading menu, even if you aren't particularly fond of fish on Fridays.

LAURENCE A. MARSCHALL, author of The Supernova Story, *is W.K.T. Sahm Professor of Physics at Gettysburg College in Pennsylvania, and director of Project CLEA, which produces widely used simulation software for education in astronomy.*

PICTURE CREDITS Cover: ©Mitch Epstein/Getty Images; pp. 4-5: ©Steve Bloom; p. 12(top): Kathie Atkinson/OSF; p. 12(middle): ©Flip Nicklin/Minden Pictures; p. 12(bottom): ©Bernard Castelein/naturepl.com; p. 13(top): ©Mary Evans Picture Library; p. 13(bottom): ©Terry Deroy Gruber/Getty Images; p. 14(top): ©Marian Bacon/Animals Animals; p. 14(bottom left): ©Roger Wood/CORBIS; p. 14(bottom right): Hannah Black; p. 16: Courtesy of the author; p. 18: ©Yale Goldman; pp. 20&22: ©Alex Wild 2004/2005; pp. 36-37: ©Seth Perlman/Associated Press; pp. 38&41: Illustrations by Ian Worpole; pp. 39&40: © 2005 Gary Braasch; p. 42(left): ©Erich Lessing/Art Resource, NY; pp. 42-43(middle): ©The British Museum, London; p. 43(top): Photograph from the National Museum of Anthropology in Mexico (Abrams book), ©Javier Hinojosa; p. 43(bottom): ©HIP/Art Resource, NY; p. 44(left): ©Malcolm E. Osman/Pitt Rivers Museum; p. 44(right): ©2006 State Hermitage Museum, Russia; p. 45(top left & right): ©Jeff Saward/www.labyrinthos.net; p.45(top middle): ©Topham/The Image Works; pp. 45(bottom) & 47: Courtesy of the author; p. 46: ©The Textile Museum, Washington DC; pp. 48-49: ©John C. Abbott Nature Photography; pp. 49(inset) 50 & 54: ©Christie Van Cleve; p. 51:Map by Joe LeMonnier; pp. 52-53: Illustration by Patricia J. Wynne; p. 56(top): ©Susan M. Glascock; p. 56(bottom): ©Pat & Chuck Blackley; p. 57: Map by Joe LeMonnier; p. 58: ©Scala/Art Resource, NY; p. 59: ©2005 Gary Braasch; p. 60: ©Anne Wertheim Rosenfeld; p. 63: ©NASA, ESA, H. Weaver, A. Stern, & the HST Pluto Companion Search Team; p. 72: ©Christian Ziegler

EXPLORER GUIDE

nature.net

Gas Trap

By Robert Anderson

The steady blue flame glowing beneath my pancake griddle is, for the most part, burning methane. A simple molecule with four hydrogen atoms bonded to a central carbon (CH_4), methane is a clear, odorless gas. Although it cooks our comfort food and is a vital source of energy, methane also has a dark side. It is a powerful greenhouse gas, trapping twenty times as much heat in the atmosphere as a similar volume of carbon dioxide.

The real worry is the methane now trapped in ice. At low temperatures (around thirty-two degrees Fahrenheit) and moderate pressures (about thirty atmospheres), methane and water form an ice called methane hydrate. Relatively unknown until the 1970s, most methane hydrate is locked up in sediments along continental shelves. A smaller amount is buried in Arctic permafrost. Together, those deposits hold twice as much carbon as all the Earth's reserves of coal, oil, and natural gas combined. If even a small percentage of that methane hydrate melts, it could dramatically increase global warming.

At the National Oceanic and Atmospheric Administration's "Ocean Explorer" Web site (oceanexplorer.noaa.gov/explorations/deepeast01/background/beneath/beneath.html), Peter A. Rona, a marine geologist at Rutgers University in New Brunswick, New Jersey, conducts a virtual tour to the depths of the eastern Atlantic. There, as he shows the viewer, are vast reserves of methane hydrate. At the bottom of the Web page is a diagram comparing the simple lattice of ordinary ice with the more complex one of methane hydrate. The methane molecules in the complex ice are locked inside "cages" of frozen water.

Methane hydrate does have a good side. Entire communities of deep-sea creatures have evolved the means to thrive on its energy. Texas A & M University's Web page "Lair of the 'Ice Worm'" (www-ocean.tamu.edu/Quarterdeck/QD5.3/macdonald.html) describes a colony of polychaete worms whose home is a hydrocarbon seep at the bottom of the Gulf of Mexico.

If investigators figure out how to tap methane hydrate safely, the deposits may help meet humanity's insatiable demand for fossil fuels. Listen to "Mining Methane" at www.cbc.ca/quirks/archives/03-04/jan03.html to hear Scott Dallimore, a geotechnical engineer at the Geological Survey of Canada, describe his team's exploration of hydrate deposits in the Arctic. For a world map of known methane hydrate deposits, go to walrus.wr.usgs.gov/globalhydrate/ and choose the poster at the left in a format for either screen-viewing or printing.

The big fear of many climatologists is that some poorly understood part of Earth's climate system, pushed to a tipping point by human emissions, might trigger a runaway greenhouse effect. Perhaps the most ominous clues to the threat posed by methane hydrate come from the distant past. According to a NASA news item (earthobservatory.nasa.gov/Newsroom/NasaNews/2001/200112106303.html), 55 million years ago a large release of the frozen seafloor gas heated the Earth by thirteen degrees F. Gavin A. Schmidt, a NASA climatologist, explains how ratios of isotopes of carbon suggest that methane hydrate was to blame for that dramatic warming (www.giss.nasa.gov/research/briefs/schmidt_02/).

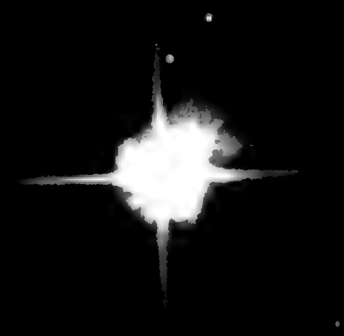
The most chilling scenario of all, however, comes from the end of the Permian period, when Earth underwent its largest mass extinction. Dan Dorritie, a paleontologist in California, regularly updates his online book on the role the he, among others, thinks methane hydrate played in that horrendous event (www.killerinourmidst.com/). Dorritie warns, it could happen again.

ROBERT ANDERSON is a freelance science writer living in Los Angeles.

Sizing Up Pluto

The runt of the solar system turns out to have three moons.

By Charles Liu



If you believed half the spam you got in your e-mail, you'd think size is everything. So pity poor Pluto. When the American astronomer Clyde W. Tombaugh discovered it back in 1930, it was immediately dubbed the ninth planet of our solar system. Most astronomers thought it was as big as the gas-giant planets Uranus and Neptune—maybe even bigger. But almost immediately after its discovery, astronomers agreed that Pluto would have to shrink; then, as telescopes got progressively more powerful, Pluto got even smaller. Today, we astronomers know it's not even as big as Earth's moon. Total shrinkage: more than twenty times the original estimate.

But Pluto lovers were in for even more distress. In 1978, when astronomers discovered Pluto's moon Charon, they realized that both bodies revolve about a center of mass that does not lie inside either one of them. Pluto was not a single planet, but half of the Pluto-Charon double-planet system (though Charon continues to be called a "moon"). Worst of all was the recent discovery of 2003 UB313, an object larger than Pluto yet farther from the Sun [*see "Number Ten?" by Charles Liu, October 2005*]. With that, the case became even stronger that Pluto was misclassified in the first place—it's not even a "real" planet!

Before you get all teary-eyed over Pluto's waning status, though, consider this: if astronomers are really so down on Pluto, why did we work so hard to launch a new spacecraft recently to probe it? Just as you should trash all that silly "ENläarge it" spam as hype, you might also delete the notion that size is all that matters in a heavenly body. In fact, in the past decade astronomers have sent several spacecraft to "minor" targets: *NEAR-Shoemaker* to the asteroid 433 Eros, *Stardust* to Comet Wild 2, and *Deep Impact* to Comet P/Tempel 1. The largest of those targets, Eros, is barely twenty miles across. Yet each of those missions has yielded important insights about the composition and history of our solar system.

As for the current mission to Pluto, *New Horizons* is perhaps the most sophisticated space probe ever launched—certainly not just a bone tossed toward a B-list planetary body. It left Earth's vicinity at nearly 36,000 miles an hour (the fastest ever launch speed) and passed the Moon's orbit in approximately nine hours. (*Apollo 11* took three days to do the same thing.) If all goes well, *New Horizons* will reach Jupiter in thirteen months, then take advantage of the giant planet's gravity to slingshot on to Pluto sometime in July 2015.

As it turns out, an unexpected bonus—two, actually—will greet *New Horizons* when it reaches its primary target: a pair of tiny moons whose existence was confirmed barely a month after launch.

Since Tombaugh's time, Pluto may have given up its claim to be a gas giant, but as of this year its new status as a many-mooned planet finally enables it to join the ranks of Uranus and Neptune. In May 2005 Harold A. Weaver of Johns Hopkins University's Applied Physics Laboratory in Laurel, Maryland, and S. Alan Stern of the Southwest Research Institute in Boulder, Colorado, trained the Hubble Space Telescope on Pluto for some of its most detailed images ever. The astronomers saw two dots of light, each about 35,000 miles from Pluto—much farther from the planet than Charon is, but only about one-seventh the distance between the Moon and Earth. To verify that the dots were moons, the team reviewed past data and found evidence of them, in different positions with respect to Pluto, on images dating back to 2002. They calculated orbital paths for the two objects and took

(Continued on page 66)

Enhanced-color images of Pluto made by the Hubble Space Telescope on February 15, 2006 (top of page), and March 2, 2006 (above), reveal the faint light of two newly discovered moons (small white dots). Their movement relative to Pluto (brightest spot at center of images) over time led investigators to conclude that they orbit the planet. Charon, smaller than Pluto but substantially larger than the two new moons, appears to the upper right (in the top image) and to the upper left (in the above image) of the planet.

FYI READER SERVICE

ADVENTURE TRAVEL/TOURS

1. ADVENTURE CANADA
Travel on the 104-passenger, zodiac-equipped *M/S Explorer* and discover the art, culture and wildlife of Arctic Canada and Greenland.

2. ADVENTURE LIFE JOURNEYS
Small group travel in the Andes, Amazon, Galapagos, Patagonia, Antarctica, and Central America. Expert local guides lead our cultural and ecological explorations.

3. ADVENTURESMITH EXPLORATIONS
Small ship cruise and adventure travel experts. Explore nature up close and in style aboard luxury yachts, small ships and wilderness lodges.

4. AMAZONIA EXPEDITIONS
Award-winning Jungle Lodge in the Tamshiyacu-Tahuayo Reserve, shown to have the greatest diversity of mammals in all of the Amazon.

5. CROW CANYON ARCHAEOLOGICAL CENTER
Small-group cultural adventures led by world-renowned scholars explore some of the world's most interesting locations.

6. ECOTOUR EXPEDITIONS
Take a walk on the wild side: Explore nature with our skilled naturalist guides in the Amazon, Galapagos, Costa Rica, Peru, and Brazil. Since 1989.

7. GALAPAGOS TRAVEL
Specializing in comprehensive, educationally-oriented, professionally-led natural history tours of the Galapagos Islands. Spend 11 or 15 days touring all the significant outer islands.

8. G.A.P. ADVENTURES
Small group adventures, safaris and expeditions to all 7 continents. With a focus on culture, nature and sustainable tourism. We offer authentic, grassroots travel experiences.

9. MELANISIAN TOURIST SERVICES
Luxury expedition cruising throughout the Sepik River and Trobriand Islands aboard the *MTS Discoverer*. Customized land arrangements.

10. SERIOUS TRAVELER
Cultural Tours. Small Groups. Libya, Iran, India, Faroes, Apulia, Tibet, Myanmar, Silk Road, and Kenya! Travel Concepts International.

11. SOL INTERNATIONAL
We specialize in South America, offering exceptional nature and cultural programs to areas where wildlife abounds and indigenous communities are unspoiled.

12. TARA TOURS
Tara Tours specialize in travel to Central and South America since 1980. Free brochures and quotes.

13. TERRA INCOGNITA ECOTOURS
For trips that make a difference to you and to the places we visit. Trek Mountain Gorillas, snorkel on Barrier Reefs, rainforest hikes, whitewater rafting, and more.

14. TILLER INTERNATIONAL TOURS INC.
Ladakh Sikkim Bhutan—Wondrous eco/cultural tour from arid western Himalayas to the temperate forested eastern range, where Tibetan religion meets the 21st century.

15. ZEGRAHM EXPEDITIONS
Offers small-group expeditions to remote locations around the world. Expertly led and staffed, our programs provide the finest adventure travel experience imaginable.

AUTOMOTIVE

16. TOYOTA
As Toyota continues to expand our U.S. operations, we're working to create even more jobs and opportunities across the country. Learn more about our ten manufacturing plants, sales and marketing operations, design and R&D facilities, and how we invest in local communities.

BOOKS

17. ISLAND PRESS
A leading publisher of books about the environment for professionals, students, and general readers-from solutions oriented books to books on ideas that inform and inspire.

18. JOHNS HOPKINS UNIVERSITY PRESS
Celebrating 150 years of publishing for the world. Books about nature and science.

CANADA

19. NEW BRUNSWICK, CANADA
From the World's Highest Tides in the Bay of Fundy to rivers that reverse their flow. . . there are no small wonders in New Brunswick, Canada!

20. NEWFOUNDLAND & LABRADOR
Newfoundland and Labrador. We offer our visitors the natural wonders of whales, icebergs and seabirds framed by our dramatic seascape and landscape.

21. NOVA SCOTIA
Yes, please send me my FREE 400 page Nova Scotia Doer's & Dreamer's Travel Guide.

22. PRINCE EDWARD ISLAND, CANADA
Come experience our unique red cliffs and parabolic sand dunes and hike or bike the Confederation Trail across our Island.

CRUISES

23. AMERICAN CRUISE LINES
Enjoy scenic and culturally enriching 7-night cruises through the smooth waters of the inland passages along the eastern U.S. seaboard.

24. CLIPPER CRUISE LINE
Deluxe small-ship adventures for those seeking a more meaningful travel experience. The Americas, Antarctica, Europe, High Arctic, Far East and South Pacific.

25. ORIENT LINES
Cruise to the Mediterranean's most glamorous playgrounds. Enjoy luxury at sea, aboard the elegant mid-sized ships sophisticated travelers prefer.

26. SWAN HELLENIC CRUISES
Ocean and sea cruises, expedition and river cruises all with the accent on discovery. Exotic destinations and distinguished guest speakers.

INTERNATIONAL TRAVEL

27. BELIZE TOURIST BOARD
Catch the Adventure! From rainforest resort to Barrier Reef. Belize is only 2 hours from the USA. Belize. Mother Nature's best kept secret.

28. EGYPT
Where history began and continues. There's never been a better time to visit Egypt. Live the adventure you've always dreamed about. Visit Egypt.

29. SCOTLAND
Vibrant cities are one thing, breathtaking views another, but in the end, it is the soaring spirit of the Scottish people you will recall most fondly.

For free information from the advertisers listed below, circle the corresponding numbers on the attached postage-paid card. Mail card, fax it to 856-380-4101, or visit us at www.naturalhistorymag.com. If the card is missing, mail your request to: P.O. Box 9000, Maple Shade, NJ 08052.

INVESTMENT MANAGEMENT

30. CALVERT—INVESTMENTS THAT MAKE A DIFFERENCE®
The nation's largest family of mutual funds that integrate rigorous financial analysis with a thorough assessment of corporate integrity including environmental impact.

MARYLAND

31. CHARLES COUNTY, MD
It's for the birds! Take a hike! Hunt for fossils, golf, fish, shop. Experience the wild side of the Potomac where eagles soar.

32. CHOOSE CALVERT COUNTY, MD
Less than an hour from Washington D.C. you can discover Chesapeake Bay history. Hunt along sandy beaches for over 600 fossil species at the 15-million-year-old Calvert Cliffs. Hike 15 miles of trails and more. Deciding to visit is easy. Leaving? That's hard.

33. DORCHESTER COUNTY, MD
Destination Dorchester—Home to world-renowned Blackwater National Wildlife Refuge, excellent paddling, cycling, fishing and hunting; explore the heart of Chesapeake Country on Maryland's Eastern Shore.

34. FREDERICK COUNTY, MD
Maryland's Crossroads of History. Antiques, Battlefields, Covered Bridges, Parks, Wineries and more close to Gettysburg and Washington, DC.

35. KENT COUNTY, MD
The County of Kent is a scenic peninsula on the Chesapeake Bay, offering fishing, boating, kayaking, small beaches, awesome sunsets, museums, the "Arts," farmers' markets, and great shopping.

36. MONTGOMERY COUNTY, MD
Experience transportation history along the C & O Canal and the National Capital Trolley Museum. So many things to do with easy access to the nation's capital.

37. PRINCE GEORGE'S COUNTY, MD
Wonderful museums and historic sites, the National Wildlife Sanctuary, affordable accommodations and much more. All just minutes from Washington, DC.

38. TALBOT COUNTY, MD
Talbot County's five beautiful rivers, 602 miles of shoreline, unique charming hamlets St. Michaels, Oxford, Tilghman Island and Historic Easton offer a timeless treasury of natural beauty and history.

39. WORCESTER COUNTY, MD
Maryland's only seaside county. Visit Assateague Island National Seashore. Kayak, canoe, bird watch or golf. Stay in one of our many Bed & Breakfast Inns.

MISCELLANEOUS

40. ATHENA PUBLICATIONS, INC.
Athena Review, journal of archaeology, history and exploration, invites you to send for more information on a free issue.

41. BBC AMERICA SHOP
Bringing you the very best in British entertainment—award-winning DVDs and videos from your favorite television shows as well as movies, books, audio books and other British gifts.

42. EARTHJUSTICE
Earthjustice is a nonprofit law firm dedicated to protecting the magnificent places, natural resources, and wildlife of this earth by enforcing and strengthening environmental laws.

43. THE ST. JOE COMPANY
The St. Joe Company offers the greatest choice of authentic, organic, and original places to live, work, and escape in Florida.

MONTANA

44. CUSTER COUNTRY, MONTANA
Custer, Sitting Bull, and Lewis and Clark have been here. Why haven't you?

45. MONTANA TOURISM
Find what you're looking for in Montana! Fascinating cultural attractions, scenic beauty, outdoor adventure, enchanting lodges, shopping and western charm. Free Vacation Planner.

46. MONTANA'S MISSOURI RIVER COUNTRY
Experience dinosaur museums and field stations; scenic, unspoiled lands; wildlife watching; pioneer history; Lewis & Clark attractions and more.

47. MONTANA'S RUSSELL COUNTRY
Legendary in the paintings of yesterday and the digital pixels of today.

U.S. TRAVEL

48. ADIRONDACKS
Free Scenic Byways Road Map and Guide. Visit one of National Geographic Traveler's "50 Places of a Lifetime." Explore a land as beautiful today as it was hundreds of years ago.

49. ALABAMA GULF COAST
Spectacular beaches. Outstanding accommodations. And warmed by sunshine, history, culture and unspoiled natural beauty.

50. ASHFALL FOSSIL BEDS
A real fossil site with 3-dimensionally preserved skeletons of rhinos, horses, and camels, victims of the aftermath of a supervolcanic eruption. Located in Northeast Nebraska.

51. CHEROKEE, NORTH CAROLINA
Culture abounds in Cherokee, North Carolina in 2006. Attractions include "Unto These Hills," outdoor drama, Oconaluftee Indian Village, Museum of the Cherokee Indian, and Qualla Arts & Gallery.

52. NEW MEXICO
Where unparalleled scenic beauty, outdoor adventure, world-renowned art and cultural diversity rest under the same magical sunset.

53. NEW ORLEANS
New Orleans is back in swing—and we have never been more proud to share the music, food and history of our home.

54. NEW YORK STATE
Plan your next getaway to New York State. I LOVE NEW YORK! What a great vacation.

55. NORTH CAROLINA OUTER BANKS
The Outer Banks of NC—Immerse yourself in culture and history. Here anytime is quality time.

56. THE GREAT STATE OF TEXAS
Discover a vacation you never knew existed. Discover mountains, prairies, open skies and endless coastlines. Discover it all in your FREE Texas State Travel Guide. Discover why Texas really is like a whole other country.

(Continued from page 63)

another picture of Pluto this past February 15. Sure enough, the two dots were exactly where the calculations had predicted they would be.

Now directly confirmed as Plutonian moons, S/2005 P 1 and S/2005 P 2 will receive official names from the International Astronomical Union in due course. Meanwhile, two questions spring to mind: How did they get there? And why were they never seen before?

It's a lot easier to answer the second question than the first. Frankly, no one looked hard enough—or, more to the point, no one could see the two moons well enough in the dark. Remember how Pluto has shrunk so dramatically over the decades? Of course, Pluto never really changed size; it's held steady for eons at about 1,400 miles across. What has changed is our ability to distinguish relatively faint, little objects billions of miles from Earth. The two new moons are only about one four-thousandth as bright as Pluto—roughly the difference between a bathroom night-light and all the rest of the light bulbs in your house combined.

As for the moons' origins, the jury is still out, but Weaver and Stern present a plausible scenario. Computer simulations suggest that, like the Earth-Moon system, the Pluto-Charon system formed billions of years ago in a giant collision. An intruder may have crashed into the young Pluto, depositing much of its mass onto the planet and so increasing its size. The rest of the material may then have splashed outward into orbit around Pluto, forming Charon. Large shards from the impact may have survived while in orbit and eventually coalesced into the two small moons.

So do Pluto's new moons make the little ice ball into a big player after all? Surely any object big enough to attract not one but *three* moons deserves to be called a major planet? Well, yes and no. Pluto's trilunar system has certainly increased the planet's reputation beyond what the Pluto-Charon duo once had. But some minor planets, a.k.a. asteroids, have moons too. The first such moon, Dactyl, was discovered orbiting the asteroid 243 Ida, itself a mere thirty-five miles across, by the Galileo spacecraft more than a decade ago. It may only be a matter of time before my planetary-astronomer colleagues find an asteroid with two, three, or even more moons.

Here's the bottom line: No matter what we call it or how we classify it, Pluto will remain a fascinating object to study. It will no doubt continue to yield big scientific surprises, and ultimately, may provide new and fundamental insights into the history of our solar system. And when *New Horizons* approaches Pluto and its moons almost a decade from now, wide-eyed and angling for a better look, we will once again see that, in the grand scheme of the cosmos, it's not how much mass you have—it's how you use it.

CHARLES LIU is a professor of astrophysics at the City University of New York and an associate with the American Museum of Natural History.

THE SKY IN MAY

By Joe Rao

Mercury reaches superior conjunction, passing behind the Sun's disk, on May 18, one day after the planet crosses the ecliptic and begins to move north against the sky. Because it will also be at perihelion (the planet's closest approach to the Sun) on the 21st, the speedy planet will quickly move into view by about the 29th. On that night Mercury begins a good apparition that lasts through June. With binoculars, look for it low in the west-northwest during evening twilight. Thirty minutes after sunset Mercury shines bright at magnitude −1.1, about five degrees above the horizon.

Venus doesn't rise until shortly after first light. Once it does, however, it is so bright that its rays easily pierce the advancing veil of daylight. The planet continues to rise at dawn every morning as viewed from the mid-northern latitudes, but it doesn't get very high before it's lost in the glare of sunrise. Venus recedes from Earth as it races ahead of us in its faster orbit around the Sun. A slender crescent Moon appears well to the left and slightly above Venus on the morning of the 24th.

Mars is in the western evening sky, appearing only one-fortieth as bright as it did six months ago. And the Red Planet continues to fade, dimming in magnitude from 1.5 to 1.7. All month, it is comparable in brightness to the stars Castor and Pollux, in the constellation Gemini, the twins. Mars forms a nearly perfect straight line with Castor and Pollux on the evening of the 31st. Watch the stars for a few days before and after that date for a clear view of Mars's motion. This month, Mars moves twenty degrees east, through Gemini and into the boundaries of the dim constellation Cancer, the crab. A thin crescent Moon appears above and to the right of Mars on the evening of the 30th.

Jupiter is in the western part of the constellation Libra, the scales, this month. The planet arrives at opposition (on the opposite side of the Earth from the Sun) on the 4th, and so on that night it rises at sunset and sets at sunrise. Shining at magnitude −2.5, Jupiter is second in brightness only to Venus. By mid-month it is well up in the southeast as darkness descends and forms a rather conspicuous triangle with the stars Spica and Arcturus.

Saturn shines at magnitude 0.3 in the constellation Cancer. The gas giant is more than halfway up in the south-southwestern sky as darkness falls at the beginning of the month. It sets just after 2 A.M. on the 1st and a couple of hours earlier by month's end. On the night of the 3rd a fat crescent Moon hovers well to the right of Saturn as the pair descends in the western sky. But that is only the first of two Moon-Saturn pairings this month. On the evening of the 31st a thinner crescent Moon passes about three degrees above Saturn.

The Moon waxes to first quarter on the 5th at 1:13 A.M. and to full on the 13th at 2:51 A.M. Our satellite wanes to last quarter on the 20th at 5:20 A.M. and to new on the 27th at 1:26 A.M.

During mid-month, observers might catch a glimpse of Comet 73P/Schwassmann-Wachmann 3, a small, faint comet that completes one full circuit around the Sun roughly every 5.3 years. In 1995 it unexpectedly fractured into at least five pieces and in the process became just visible to the unaided eye. On the 12th, en route toward the Sun, the biggest of the fragments (fragment "C") passes within 7.3 million miles of Earth. For a few nights around that date the fragment might again be visible to the naked eye. The Web site tinyurl.com/8tcxz offers maps that depict the comet's track across the constellations.

Unless otherwise noted, all times are given in eastern daylight time.

Extremely Long-Necked Sauropod Named by AMNH Paleontologists


JASON BROUGHAM

Artist's conception of the living *E. ellisoni*

Two American Museum of Natural History paleontologists have described a new species of sauropod, *Erketu ellisoni*, that had an extremely elongated neck, one of the longest necks proportional to trunk height of all known sauropods. The truly impressive feature of this dinosaur was not its bulk or overall length, but the length of its neck—especially in comparison to the rest of its body. Most sauropods had long necks extending from large bodies, but *E. ellisoni* took this to an extreme. A single neck vertebra from *E. ellisoni* measures more than half a yard (nearly two feet) long. Based on the partial neck recovered from this specimen, the Museum team estimates that the full neck was more than eight yards long.

The new finding is described in the peer-reviewed journal *American Museum Novitates* by Daniel T. Ksepka, a graduate student enrolled at Columbia University who studies at the American Museum of Natural History, and Mark A. Norell, Curator in the Museum's Division of Paleontology.

The fossil, which also includes a chest plate, two lower leg bones, and a potato-sized anklebone, was discovered in 2002 during the exploration of a new site, Bor Guvé, as part of the Museum's annual joint paleontological expeditions to the great fossil beds of Mongolia's Gobi Desert with the Mongolian Academy of Sciences.

The neck vertebrae of *E. ellisoni* illustrate some of the interesting evolutionary strategies sauropods used to reduce the burden of their long, cumbersome necks. The sides of the bones feature large concavities where air sacs would have existed. Computed tomography (CT) scans reveal that the vertebrae are not solid, but instead are filled with numerous small pneumatic chambers that would have reduced their weight. Also, spines along the top of some of the vertebrae were split into two parallel tracks rather than one, as with the human spine. The channel between the two spine rails probably allowed room for a ligament to help support the neck.

The generic name for the new sauropod comes from Erketü, one of 99 deities chronicled from pre-Buddhist Mongolian shamanistic tradition; Erketü was the god of might. The species name honors Mick Ellison, Senior Principal Artist at the Museum, whose work has significantly contributed to dinosaur research.

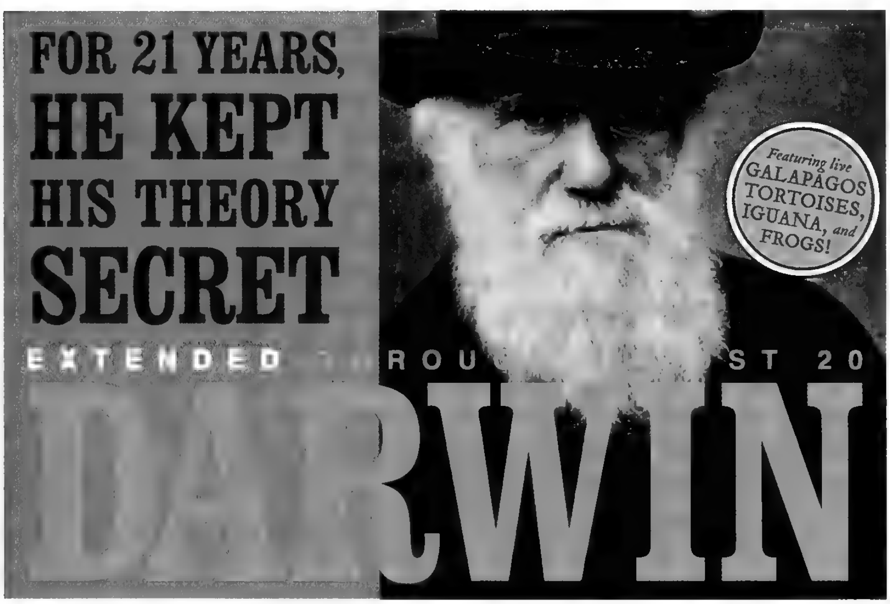
Extended until June 23, 2006!

The Butterfly Conservatory: Tropical Butterflies Alive in Winter

D FINNIN/AMNH

Kids and adults alike are mesmerized and delighted by the fluttering iridescent creatures that might hitch a ride on an arm or shoulder. Truly a hands-on learning experience, *The Butterfly Conservatory* has been a favorite of Museum visitors for eight years.

This exhibition is made possible, in part, through the generous support of JPMorgan Chase.



Lizards & Snakes: Alive!

Opening June 24, 2006

Live lizards and snakes are the center of attention in this engaging exhibition that will explore these creatures' remarkable adaptations, including projectile tongues, deadly venom, amazing camouflage, and sometimes surprising modes of movement. Fossil specimens, life-size models, videos, and interactive stations will complement the live animals representing 20 species.

PEOPLE AT THE AMNH

Raymond Salva
Assistant Director, Traveling Exhibitions and Planetarium Shows

D FINNIN/AMNH

When Ray Salva joined the Museum in September 2003, he was looking for a career change, seeking rewards of a more personal nature. After years of working in the corporate sector, he hoped to apply his skills to a meaningful role in a not-for-profit organization. Even as he describes his job here, after several years, his enthusiasm and appreciation for the Museum are apparent. "It is a rare honor to work with such dynamic, focused, and dedicated teams in an environment brimming with stimuli, where you are constantly learning and growing."

As an Assistant Director in the Department of Business Development, Ray works to create relationships with domestic and international cultural institutions to bring AMNH's state-of-the-art planetarium shows, traveling exhibitions, *Science Bulletins* programming, and the Digital Universe to museum, science center, and planetarium audiences worldwide. Among his greatest challenges thus far was organizing the very first collaborative production project between the Museum and partners in Asia. Most recently, Ray put together the collaboration to create the Museum's new Space Show, *Cosmic Collisions.*

"In helping to bring the Museum's work around the world, the rewards have been immeasurable. It's incredibly satisfying to know that my role plays a part in our educational outreach and the overall impact that AMNH has on its visitors, as well as the visitors to our many partner institutions around the globe."

When not working, Ray and his wife of 16 years take full advantage of all that living in New York has to offer, enjoying dining, live music, art, theater, and baseball.

Museum Events

AMERICAN MUSEUM OF NATURAL HISTORY

www.amnh.org

D. FINNIN/AMNH

The scrupulous re-creation of Darwin's study in the exhibition *Darwin*

EXHIBITIONS

Darwin
Through August 20, 2006
Featuring live animals, actual fossil specimens collected by Charles Darwin, and manuscripts, this magnificent exhibition offers visitors a comprehensive, engaging exploration of the life and times of Darwin, whose discoveries launched modern biological science.

The American Museum of Natural History gratefully acknowledges **The Howard Phipps Foundation** for its leadership support. Significant support for *Darwin* has also been provided by Chris and Sharon Davis, Bill and Leslie Miller, the Austin Hearst Foundation, Jack and Susan Rudin, and Rosalind P. Walter. Additional funding provided by the Carnegie Corporation of New York, Dr. Linda K. Jacobs, and the New York Community Trust–Wallace Special Projects Fund. *Darwin* is organized by the American Museum of Natural History, New York (www.amnh.org), in collaboration with the Museum of Science, Boston; The Field Museum, Chicago; the Royal Ontario Museum, Toronto, Canada; and the Natural History Museum, London, England.

The Butterfly Conservatory
Through June 23, 2006
A return engagement of this popular exhibition includes up to 500 live, free-flying tropical butterflies in an enclosed habitat that approximates their natural environment.

This exhibition is made possible, in part, through the generous support of JPMorgan Chase.

Voices from South of the Clouds
Through July 23, 2006
China's Yunnan Province is revealed through the eyes of the indigenous people, who use photography to chronicle their culture, environment, and daily life.

The exhibition is made possible by a generous grant from Eastman Kodak Company. The presentation of this exhibition at the American Museum of Natural History is made possible by the generosity of the Arthur Ross Foundation.

Vital Variety
Ongoing
Beautiful close-up photographs highlight the diversity of invertebrates.

LECTURES

Darwin in the 21st Century: Science at AMNH
Wednesday, 5/3, 7:00 p.m.
Museum curators provide insights into the work being done in their areas of research.

The River of Doubt
Thursday, 5/4, 7:00 p.m.
Candice Millard, former *National Geographic* staff writer, discusses Roosevelt's hardships in the Amazonian rain forest.

Adventures in the Global Kitchen: Michael Pollan and Peter Hoffman on the "Cornification" of America
Tuesday, 5/16, 7:00 p.m.
With Michael Pollan, *Botany of Desire*, and Peter Hoffman, chef and owner of Savoy.

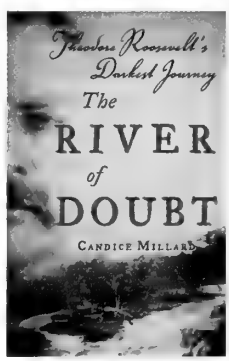
Vietnam: A Natural History
Tuesday, 5/23, 7:00 p.m.
With Eleanor J. Sterling, Director of the Museum's Center for Biodiversity and Conservation, and Martha M. Hurley and Le Duc Minh, Biodiversity Scientists.

FIELD TRIP

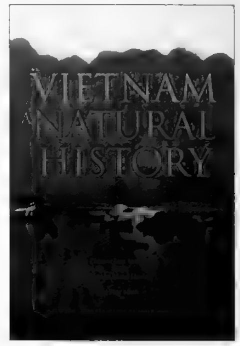
Evening Bat Walks in Central Park
Friday, 5/12, and Friday, 5/19, 7:30 p.m.
Join the New York Bat Group for a walk through Central Park at dusk.

FAMILY AND CHILDREN'S PROGRAMS

Science in the Galápagos: Bird Adaptations
Sunday, 5/21, 11:00 a.m.–12:00 noon and 1:00–2:00 p.m. (Ages 5–7, each child with one adult)
An introduction to birds of the Galápagos.



Observing Worms
Sunday, 5/7, 11:00 a.m.–12:30 p.m. (Ages 4–6, each child with one adult)
Observe live worms and learn how they transform the soil.



Adventures in the Global Kitchen for Kids and Families: A Taste of Brazil
Saturday, 5/6, 12:00 noon
Food, culture, and authentic recipes.

Stories of the Sky
Saturday, 5/6, 11:00 a.m.–12:30 p.m. (Ages 4–5, each child with one adult) and 1:30–3:00 p.m. (Ages 6–7, each child with one adult)
Learn the ancient tales of the Sun, Moon, and stars.

Astrofavorites: NASA Astronaut Training Mission
Three Thursdays, 5/11–25, 4:00–5:30 p.m. (Ages 4–6, each child with one adult)
Learn about the human body in space and more.

STARRY NIGHTS
Live Jazz

ROSE CENTER FOR EARTH AND SPACE

6:00 and 7:30 p.m.

Friday, May 5
David Weiss

Starry Nights is made possible, in part, by Fidelity Investments.

Robots In Space II (Intermediate)
Three Wednesdays, 5/10–24, 4:00–5:30 p.m. (Ages 8–10)
Design increasingly complex robots.

Space Explorers: Star Party
Tuesday, 5/9, 4:30–5:30 p.m. (Ages 10 and up)
On the second Tuesday of each month, kids (and their parents) can learn under the stars of the Hayden Planetarium.

NASA/JPL-CALTECH/R. A. GUTERMUTH (HARVARD-SMITHSONIAN CFA)

Reflection nebula NGC 1333

Dr. Nebula's Laboratory: Planetary Vacation
Sunday, 5/21, 2:00–3:00 p.m. (For families with children ages 4 and up)
Join Scooter to track Dr. Nebula's voyage to explore the planets and moons of our solar system.

HAYDEN PLANETARIUM PROGRAMS

TUESDAYS IN THE DOME

Virtual Universe
Veni Vidi Venus
Tuesday, 5/2, 6:30–7:30 p.m.

This Just In...
May's Hot Topics
Tuesday, 5/16, 6:30–7:30 p.m.

Celestial Highlights
All Things Being Equal...
Tuesday, 5/30, 6:30–7:30 p.m.

LECTURES

Visit www.amnh.org/hayden for details on May Frontiers in Astrophysics and Distinguished Authors in Astronomy lectures.

HAYDEN PLANETARIUM SHOWS

Cosmic Collisions
Journey into deep space—well beyond the calm face of the night sky—to explore cosmic collisions, hypersonic impacts that drive the dynamic formation of our universe. Narrated by Robert Redford.

Cosmic Collisions was developed in collaboration with the Denver Museum of Nature & Science; GOTO, Inc., Tokyo, Japan; and the Shanghai Science and Technology Museum.
Made possible through the generous support of CIT.
Cosmic Collisions was created by the American Museum of Natural History with the major support and partnership of the National Aeronautics and Space Administration's Science Mission Directorate, Heliophysics Division.

SonicVision
Fridays and Saturdays, 7:30 and 8:30 p.m.

Hypnotic visuals and rhythms take viewers on a ride through fantastical dreamspace.

SonicVision is made possible by generous sponsorship and technology support from Sun Microsystems, Inc.

LARGE-FORMAT FILMS

LeFrak IMAX Theater
Galápagos explores the unique fauna of the islands and the surrounding sea.

IMAX films at the Museum are made possible by Con Edison.

INFORMATION
Call 212-769-5100 or visit www.amnh.org.

TICKETS AND REGISTRATION
Call 212-769-5200, Monday–Friday, 9:00 a.m.–5:00 p.m., or visit www.amnh.org. A service charge may apply.
All programs are subject to change.

AMNH eNotes delivers the latest information on Museum programs and events to you monthly via email. Visit www.amnh.org to sign up today!

Become a Member of the American Museum of Natural History

As a Museum Member, you will be among the first to embark on new journeys to explore the natural world and the cultures of humanity. You'll enjoy:

- Unlimited free general admission to the Museum and special exhibitions, and discounts on Space Shows and IMAX films
- Discounts in the Museum Shops and restaurants and on program tickets
- Free subscription to *Natural History* magazine and to *Rotunda*, our newsletter
- Invitations to Members-only special events, parties, and exhibition previews

For further information, call 212-769-5606 or visit www.amnh.org/join.

ENDPAPER

My Kingdom for a Crown

By Roland W. Kays

The first time my colleagues and I captured Bobby, an oversize ocelot, I knew he was the local king. At thirty-four pounds, he was the largest ocelot we had ever seen—and certainly the largest on Panama's Barro Colorado Island (BCI). It was clear he was a fighter, fresh from battle—and not against some easy, smaller prey, but with other, fearsome ocelots. These predators often rely on size and strong, sharp teeth to defend turf and establish social rank. Many of Bobby's battle wounds came from an ocelot's bites; he had tooth marks on his forehead, two punctures in his chest, and a deep gash across his left nostril. Ricardo S. Moreno, now a graduate student in wildlife ecology at the University of Costa Rica, was my trap-and-release partner that day. "I'd hate to see the other guy," he quipped.

Stalking the forest at night, an ocelot searches for a meal (above). Turf battles with other ocelots or tussles with prey severely damaged Bobby's canine teeth (skull at right); the broken canines may have led to his demise.

Later that year Ricardo did see the other guy. Ricardo was out one night, radio-tracking a male ocelot some years younger than Bobby. Just as Ricardo crested a hill, he caught the very end of an ocelot fight. Bobby was standing unfazed in the middle of the trail, while "the other guy" was tumbling down a hillside. Then, with a glance back at the slack-jawed Ricardo, Bobby sauntered leisurely down the trail. The King was at the top of his game.

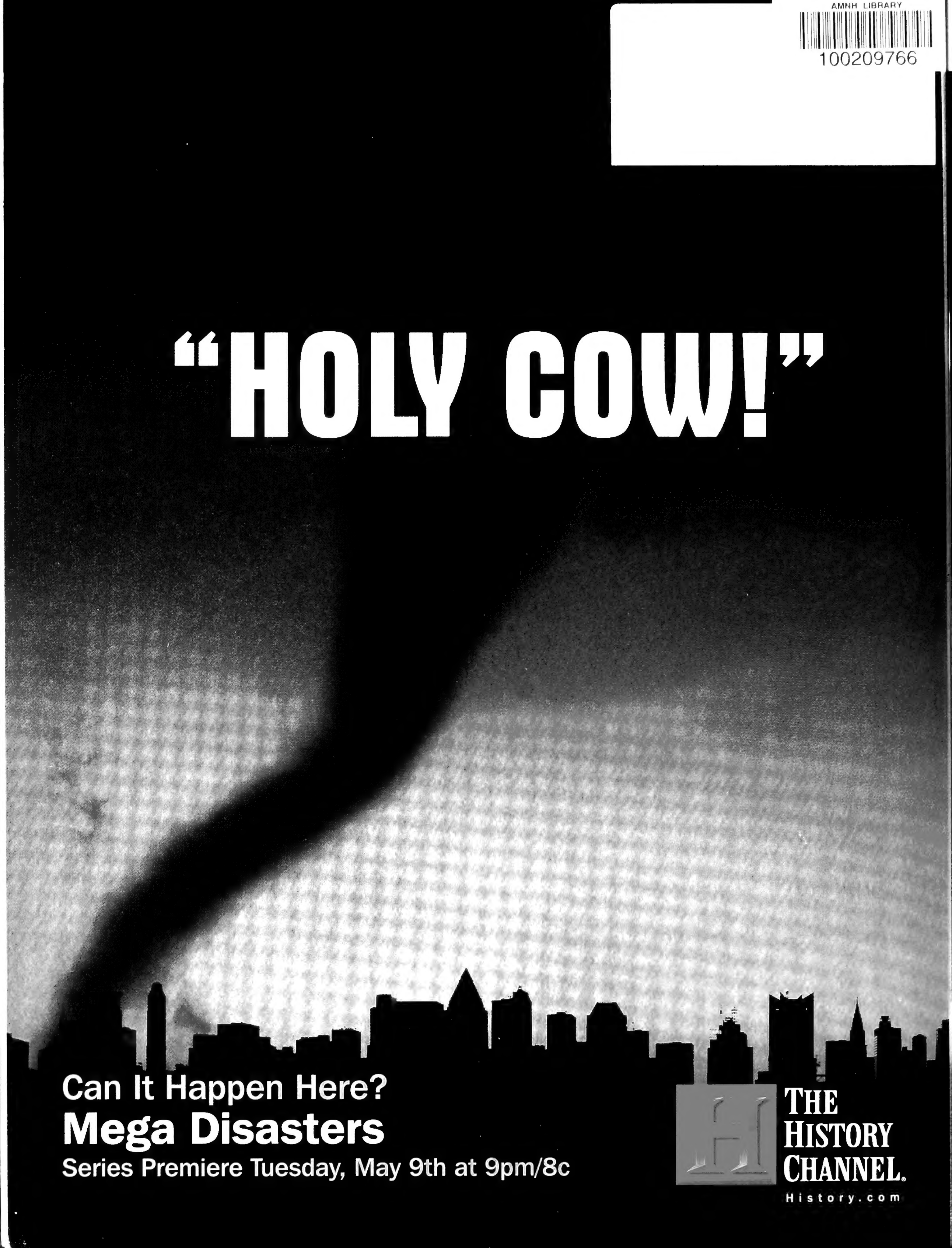
For the next two years we tracked Bobby with various equipment, old and new. He covered more than three and a half square miles on his nightly patrols—just over half the island. Once, we inadvertently caught Bobby in a trap intended for a puma, baited with a red brocket deer that we presumed had been killed by the puma the night before. Finding Bobby in the trap was a shock, but it did allow us to check his weight and replace his radio collar before its batteries ran down. We were stunned by his new weight: forty-one pounds. That made Bobby the largest ocelot in the world—now or ever, as far as we can determine from museum records and published studies.

Carnivores lead bloody lives, killing every time they need a snack. So it's no surprise their aggressions spill into their social lives as well. All fifteen ocelots we have captured on BCI have had battle scars, even the females; the worst case was a male that had lost his left ear. Most flesh wounds heal, but broken teeth—another fight casualty—do not. Canine teeth can break in fights with other ocelots, or while the animal is trying to catch prey, such as agoutis or sloths; broken teeth are common in all older carnivores. Not only does a broken canine compromise defense, but it also makes it much harder to get the next meal. That may have been what led to Bobby's demise.

Three and a half years after our first encounter with Bobby, we found his rotting remains being pecked at by a king vulture. His canines were reduced to broken stubs with exposed-pulp cavities that held arteries and nerves. Ellis J. Neiburger, a forensic dentist based near Chicago, noted that Bobby's exposed pulp "would hurt and make this critter rather nasty in temperament." Certainly his stubs would have done little for him in dominance battles. Bobby probably stumbled from his social throne before he ended up in the streambed where we found him dead.

I picked Bobby up, wrapped him in wire mesh, and buried his carcass under leaf litter to let the insects clean the bones. I realized that Bobby had claimed a special place in my memory with his ferocity and strength, even though some new animal had already claimed the role of top ocelot. But would the other BCI cats miss Bobby, or celebrate his reign? Apparently not. When I went back to retrieve his cleaned bones, I found that another ocelot had paid final respects . . . by depositing scat on top of Bobby's bones. It's not easy being king.

ROLAND W. KAYS is the curator of mammals at the New York State Museum in Albany, and a research associate at the Smithsonian Tropical Research Institute in Panama.


"HOLY COW!"
Can It Happen Here?
Mega Disasters
Series Premiere Tuesday, May 9th at 9pm/8c
THE HISTORY CHANNEL.
History.com